

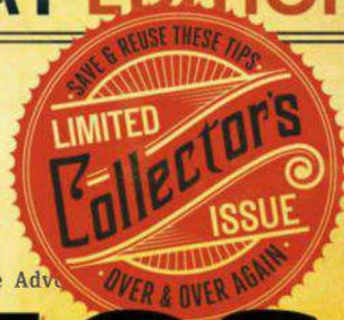
SPECIAL **110** *th* ANNIVERSARY EDITION

PopularMechanics.com

March 2012

Popular Mechanics

Science Technology Automotive Home Advice



BEST TIPS EVER

The 110

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PLUS: The Invention That
Started NASCAR's
Horsepower War **p. 68**

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Suction Cup
Mount



Handlebar
Seatpost Mount

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68 The Spring That Revolutionized Nascar

A simple piece of coiled steel wire triggered a wave of high-performance engineering advances that changed the stock car racing world. **BY LARRY WEBSTER**

74 Unacceptable Risk: Cheap Buses, Fatal Rides

Are budget motorcoach businesses out of control? PM investigates the suspect practices—and rise in deadly crashes—in the industry. **BY KALEE THOMPSON**

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Cross a soapbox derby with a sculpture exhibit, and toss in a triathlon. That's the Kinetic Grand Championship, a three-day race where art and engineering collide. **BY JAMES VLAHOS**

*On
the
cover*

In the spirit of DIY we teamed up with type designer Jordan Metcalfe to create the lettering on this month's cover. Sketched using good ol' pencil and paper, then digitally refined, his treatment is a tribute to the look and printing styles of our early days.

PHOTOGRAPH BY **DWIGHT ESCHLIMAN** PROP STYLING BY **MEGAN CAPONETTO**

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Once a symbol of luxury, the power antenna needs some care to keep it flying high.

It's almost too bad that telescoping antennas have gone out of style; they are actually pretty elegant, albeit in a Rube Goldberg kind of way.
—DIY Auto, "Stuck at Half-Mast," page 99

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99 Stuck at Half-Mast Not getting a rise out of your telescoping antenna? We've got the fix for these finicky throwbacks.
101 Car Clinic Why driving on a spare tire too long is not only dangerous, but also harmful to your ride. **Plus:** Lifting old bumper stickers; how to slow down a twitchy turn signal.

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At Combat Outpost Ghormach in Afghanistan, Air Force Tech. Sgt. Emory Sims (left) of Yale, Mich., and Master Sgt. Pat Bridges of Memphis, Tenn., savor each issue of PM. "It gives us fantasies of being back home—where we can fix things using the correct tools and parts," they write.

Secret War," January), you should keep it on computers that are not connected to the Internet. Online hackers cannot get through a connection that does not exist. But the threat of individuals hacking and spying within a company's computer system will always be there, as many companies that had computer networks before they had Internet connections have learned.

BOB ACKLEY EMERSON, IA

Air-Race Adjustment

Safety should always be the prime concern of air shows (Tech Watch, "Reno Air Race Crash," January), even if making them safer means moving the viewing site farther from the action. No one should have to put his or her life at risk to be entertained.

STEPHEN LICHOTA GOODHELLS, MI

Higher Education Trap

I've been waiting for someone to write about the unbelievable cost of an undergraduate degree ("The College Bubble," January). The education industry should be ashamed to saddle young people with such outrageous loans. Libraries offer knowledge for free. We should encourage a recognized certification system in which students can learn on their own and then seek certification in a field of their choice. Let's give the colleges and universities some competition.

PHILIP HILL ISHPERING, MI

A contributing factor to the surging costs of tuition is the easy access to credit—just like in the housing market. Employed people can barely refinance their homes, yet unemployed students are handed massive loans that in many cases are equivalent to a mortgage.

RALPH BOUVY PLANO, TX

Prevent a Hack Attack

If you want your personal and proprietary data safe from digital spies ("The

CONGRATULATIONS to senior correspondent Jeff Wise, whose story "What Really Happened Aboard Air France 447" (popularmechanics.com) was named one of the **best long-form journalism pieces of the year** by Longreads.com. *The Economist* called the story "**damning and heart-stopping**," and our readers, including many pilots, agreed. "Wow, I was holding my breath until the very end," reader Gui Ambros commented via Facebook. Read highlights of the gripping story beginning on page 22.

From our fans
and followers



Hello, PM readers on Facebook and Twitter—and thank you for responding to our stories. Here are some recent comments:

"MythBuster Adam Savage: *SOPA Could Destroy the Internet as We Know It*," popularmechanics.com: Totally agree! No matter your politics, [the Stop Online Piracy Act] is a terrible piece of legislation that would give far too much power to government and corporate entities.

PAT MOORE, VIA FACEBOOK

New episode: Will SOPA destroy the Internet? (SPOILER ALERT) Myth confirmed.

BRENT GRIMM, VIA FACEBOOK

"The 100 Hottest Cars of All Time," popularmechanics.com: Omitting the DeLorean DMC-12 from this list is poor judgment. None of these can be fitted with a flux capacitor.

JAY FURY, VIA FACEBOOK

As the dad, I have first dibs on each new issue of POPULAR MECHANICS, but I can't lay it down or my sons snatch it. @CAVECRASHER, VIA TWITTER

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do you
think?

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Trying to quit smoking but need some help? Talk to your doctor to see if NICOTROL Inhaler—the inhaled prescription nicotine replacement therapy—may be right for you.

NICOTROL Inhaler, when used as part of a comprehensive behavioral smoking cessation program, may help you quit smoking by reducing your urge to smoke.¹

For more information on NICOTROL Inhaler, visit www.Nicotrol.com/2012

Indication

NICOTROL Inhaler is indicated as an aid to smoking cessation for the relief of nicotine withdrawal symptoms. It is available only by prescription and is recommended for use as part of a comprehensive behavioral smoking cessation program.

Important Safety Information

Do not use the NICOTROL Inhaler if you are hypersensitive or allergic to nicotine, menthol, or to any ingredient in the product.

If you have cardiovascular, peripheral vascular, or bronchospastic diseases including asthma or chronic pulmonary disease, talk to your doctor about using the NICOTROL Inhaler. If you are under a doctor's care for any condition, you should first discuss with your doctor the potential risks of using this product.

You should stop smoking completely before using the NICOTROL Inhaler. You should not smoke or use other nicotine-containing products while under treatment with the NICOTROL Inhaler.

Because nicotine is addictive, it is possible to become dependent on the NICOTROL Inhaler. It is important to use it only for as long as needed to overcome your smoking habit. The safety of treatment with the NICOTROL Inhaler for periods longer than 6 months has not been established, and such use is not recommended.

Please see Brief Summary of Important Risk Information for NICOTROL Inhaler on the back.

A special note about children and pets: The NICOTROL Inhaler can cause serious illness or be fatal in children and pets—even in very small amounts. If a child chews on or swallows new or used NICOTROL Inhaler cartridges, immediately call a doctor or call your regional poison center.

The specific effects of the NICOTROL Inhaler treatment on fetal development and nursing infants are unknown. Therefore, pregnant and nursing smokers should be encouraged to attempt cessation using educational and behavioral interventions before using pharmacological approaches.

You are likely to experience mild irritation of the mouth or throat, or cough when you first use the NICOTROL Inhaler. In clinical trials, the frequency of mouth or throat irritation, or coughing declined with continued use. The most common nicotine-related side effect was upset stomach. Other nicotine-related side effects were nausea, diarrhea, and hiccup. Smoking-related side effects included chest discomfort, bronchitis, and high blood pressure.

It is important to tell your doctor about any other medications you may be taking because they may need dosage adjustment.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

1. Nicotrol Inhaler [prescribing information]. New York, NY: Pfizer Inc; 2008.



10 mg per cartridge (4 mg delivered)

Important Facts About NICOTROL Inhaler

This information does not take the place of talking to your doctor about your medical condition or your treatment.

What is the most important information I should know about NICOTROL Inhaler?

Do not use NICOTROL Inhaler if you are hypersensitive or allergic to nicotine or to menthol.

Because you are already addicted to the nicotine in cigarettes, it is possible to stay dependent on the lower dose of nicotine found in the NICOTROL Inhaler. It is important to use the Inhaler for only as long as directed by your doctor to overcome your nicotine addiction and smoking habit.

People who use NICOTROL Inhaler with a comprehensive behavioral smoking cessation program are more successful in quitting smoking. This program can include support groups, counseling or specific behavior change techniques.

Remember:

- **Do not use more than 16 cartridges each day unless directed to do so by your doctor**
- **Do not use NICOTROL Inhaler longer than 6 months**

Keep out of reach of children and pets. The NICOTROL Inhaler can cause serious illness in children and pets—even in very small amounts. If a child chews on or swallows NICOTROL Inhaler cartridges, call a doctor or Poison Control Center.

NICOTROL Inhaler may cause side effects. Many people experience mild irritation of the mouth or throat and cough when they first use the NICOTROL Inhaler. Most people get used to these effects in a short time. Stomach upset may also occur. Nicotine from any source can be toxic and addictive.

If you are pregnant or breast-feeding, only use this medicine on the advice of your health care provider. Smoking can seriously harm your child. Try to stop smoking without using any nicotine replacement medicine. This medicine is believed to be safer than smoking. However, the risks to your child from this medicine are not fully known.

What should I know before I start using NICOTROL Inhaler?

Commit yourself – NO SMOKING! For the NICOTROL Inhaler to help, you must be firmly committed to quitting! **Stop smoking** as soon as you **start using the Inhaler**. Do not smoke or use any other tobacco products at any time while using the NICOTROL Inhaler.

Nicotine overdose can occur. If symptoms of overdose occur, call a doctor or Poison Control Center immediately. Overdose symptoms include: bad headaches, dizziness, upset stomach, drooling, vomiting, diarrhea, cold sweat, blurred vision, hearing difficulties, mental confusion, weakness and fainting.

What is NICOTROL Inhaler?

NICOTROL Inhaler helps you quit smoking by reducing your urge to smoke. Success in quitting with nicotine replacement therapy (such as NICOTROL Inhaler) usually involves behavior change. Your doctor may adjust the number

of Inhaler cartridges during the first few weeks. As your body adjusts to not smoking, your doctor will either tell you to stop using the Inhaler or slowly reduce the dose.

What is a nicotine replacement therapy?

Nicotine replacement products are one type of smoking cessation product. Designed to wean your body off cigarettes, they supply you with nicotine in controlled amounts while sparing you from other chemicals found in tobacco products.

What should I tell my healthcare provider before using NICOTROL Inhaler?

Tell your doctor if you have:

- heart problems (recent heart attack, irregular heartbeat, severe or worsening heart pain)
- allergies to drugs
- high blood pressure
- diabetes requiring insulin
- stomach ulcers
- kidney or liver disease
- overactive thyroid
- wheezing or asthma

Tell your doctor about any medicines you are taking—the dosages may need to be changed. Check with your doctor before taking any new medicine while using NICOTROL Inhaler.

What are the possible side effects of NICOTROL Inhaler?

You may experience mild irritation of the mouth or throat and cough when you first use the NICOTROL Inhaler. You should get used to these effects in a short time. Stomach upset may also occur.

Tell your doctor if you have any side effect that bothers you or that does not go away. Call your doctor for medical advice about side effects.

How do I use NICOTROL Inhaler?

Follow doctor's directions. Stop smoking completely during the NICOTROL Inhaler treatment program. See full Patient Information for additional details.

How should I store NICOTROL Inhaler?

- Store cartridges at room temperature, not to exceed 77° F (25° C)
- If you keep cartridges in car, be careful: interiors heat up quickly
- Protect from light
- Clean mouthpiece regularly with soap and water

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch, or call 1-800-FDA-1088.

Need more information? Ask your doctor or healthcare provider. Talk to your pharmacist. Visit to www.NICOTROL.com or call 1-800-222-7200.

References: 1. Nicotrol Inhaler [prescribing information]. New York, NY: Pfizer Inc; 2008. 2. FDA 101: Smoking cessation products. U.S. Food and Drug Administration Web site. <http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm198176.htm>. Accessed November 14, 2011.

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Tech Watch

43'



6'

The business end of Harriet the tunnel-boring machine has fearsome incisors and crushers that can chew up 5 linear feet of rock per hour.

Miami Slice

At 43 feet in diameter and 457 feet long, the tunnel-boring machine (TBM) creating the Port of Miami Tunnel is among the largest of its type. Unfortunately, Harriet, as the \$45 million giant is known, also happens to be slow. In the 35 days after she broke ground on Nov. 11, 2011, Harriet progressed just 130 feet. By June, she's scheduled to carve out 4200 linear feet beneath Biscayne Bay.

Project vice president Chris Hodgkins attributes the snail's pace in part to the porous limestone that the 2800-ton TBM must plow through while cutting two parallel tunnels between Watson and Dodge islands. (The second tunnel is due for completion by spring 2013.) The tunnels will be a boon to the tourism and shipping industries; they will also ease traffic in downtown Miami by diverting cargo trucks



John Schussler
Senior Engineer
Mazda North American Operations

IF IT'S NOT BROKEN... FIX IT.

For over 90 years, an obsession has pushed us to keep improving how our cars look, how they drive and how they make you feel behind the wheel. It's in our DNA. It drove us to successfully engineer our revolutionary rotary engine, and it's driven us to reimagine the automobile as a whole today.

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Reimagining the automobile wasn't the goal, it just ended up that way. But that's who we are, and that's what we do. Because for us, if it's not worth driving, it's not worth building.™

Learn more about SKYACTIV® TECHNOLOGY at MazdaUSA.com/skyactiv

Meet our engineers and experience more Mazda stories at facebook.com/mazda

We build Mazdas.

What do you drive?

zoom-zoom

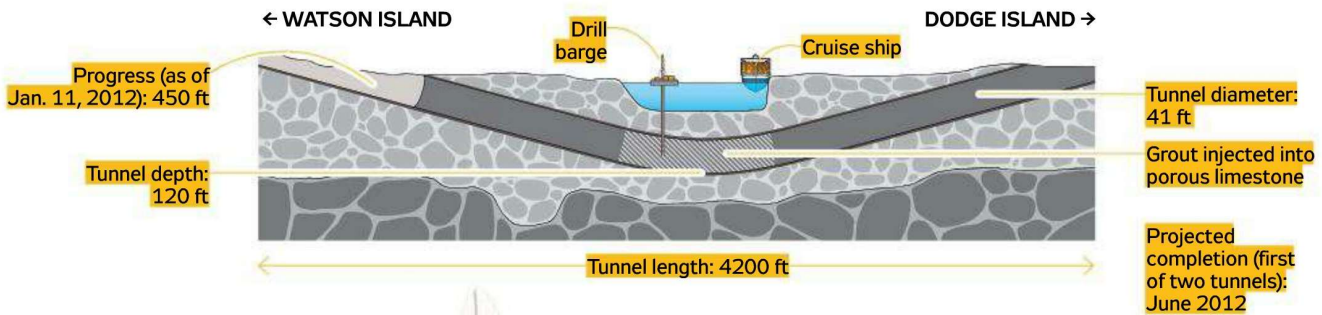


and cruise-passenger buses.

"We have a Swiss-cheese situation we're trying to address," Hodgkins tells *POPULAR MECHANICS*. To fill in the nooks and crannies, a "drill and fill" operation pumps in grout to shore up the cutting path. This is particularly painstaking beneath Government Cut, a shipping channel between Miami and the Atlantic. There, drilling barges must

stop work to make way for cargo ships and cruise liners. "We can't get in the way of the mother's milk of the economy," says Hodgkins, who claims the project is on schedule despite the obstacles.

But in addition to Harriet's awesome power and Hodgkins's troubleshooting, the project's success relies on one other ingredient: patience. — AMANDA DEMATTO



TW UPDATE

Self-Powered Cyborg Bugs

Insects guided by remote control have been around for a few years (*Tech Watch*, June 2009). But they continue to have the same problem as many tech gadgets: short battery life. University of Michigan engineers propose to fix this by gleaning energy from the insects themselves. The researchers attached piezoelectric harvesters to generate power from the wing movements of green June beetles. Other power-generation methods could include thermoelectric devices to tap body heat, and solar cells. The electricity would run cameras, mics, and gas detectors, making cyborg insects ideal first responders in cramped, hazardous situations.

— ALEX HUTCHINSON



QUICK HITS



SPACE, OR SOMETHING LIKE IT ➤ A massive new cryogenic vacuum chamber at the German Aerospace Center in Göttingen will offer the interplanetary version of a wind tunnel for satellite and spacecraft testing. Researchers evacuate the 39-foot-long, 16-foot-wide "space tunnel" with a special cryogenic helium pump that creates a space-like vacuum and temperatures as low as minus 450 F. One of the key goals of the facility is to test ion-propulsion systems, which use electricity rather than combustion to accelerate satellites and spacecraft.



THE AIR FORCE GETS ITS BIGGEST BOMB ➤ The Air Force Global Strike Command received its first GBU-57A/B Massive Ordnance Penetrator in September 2011. Guided by Global Positioning System, it is America's largest non-nuclear bomb, packing 5300 pounds of explosives and measuring 20.5 feet long, according to the Pentagon. The bomb can penetrate up to 200 feet of reinforced concrete before exploding—useful in destroying underground bunkers like ones in Iran and North Korea. The weapon will be carried by B-2 stealth and B-52 long-range bombers.

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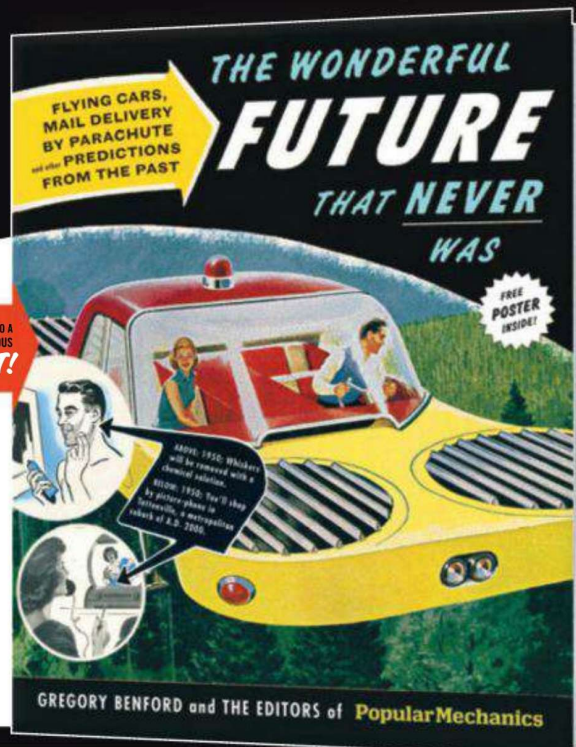


Over the decades, scientists have peered into their crystal balls, envisioned the world to come...and shared their predictions with readers of POPULAR MECHANICS.

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HEARST BOOKS

• WEAPONRY

The Plastic Pistol



Designed for the Austrian army by engineer Gaston Glock, the Glock 17 became the go-to handgun for European armed forces after its debut in 1982. Durable and inexpensive to produce, the Glock caught on fast in the U.S. a few years later. "If you look at handguns in America, the Glock has had the kind of revolutionary effect on the marketplace that the AK-47 has had on high-capacity rifles worldwide," says Paul Barrett, author of *Glock: The Rise of America's Gun* (Crown, 2012). Today, it's the weapon of choice of police departments and millions of civilian shooters, and has become a pop-culture phenomenon: The Glock name has been dropped in movies, rap songs, and David Foster Wallace's *Infinite Jest*. "The gun has taken on an aura beyond its use as an actual weapon," Barrett says. — ERIN MCCARTHY

■ Plastic body

The Glock's industrial-grade polymer frame keeps the weapon's loaded weight to 2 pounds, absorbs recoil, and guards against damage by salt water and sweat.

■ Trigger safety

Officers who used handguns with a traditional safety often forgot if it was on or off. The Glock's protrudes from the trigger; to fire the gun, the shooter depresses both parts in one motion. "It was marketed as an innovation," Barrett says. "It's also the reason the design has been criticized by gun-control advocates, because there's no way to put it on full safety."

■ Trigger pull

A typical revolver has a 12-pound trigger pull. The Glock's pull is just 5.5 pounds, making it easier to control. "A mediocre shooter can suddenly become more accurate," Barrett says.

■ Magazine

Shootouts in the 1980s persuaded cops that the six-round revolvers they had carried for 75 years weren't sufficient. The Glock's 17-round magazine—and other innovative components—made it an ideal weapon. "The American gun establishment was caught unaware by Glock," Barrett says. "Before they knew it, it made a huge incursion into their market."

• MILESTONE

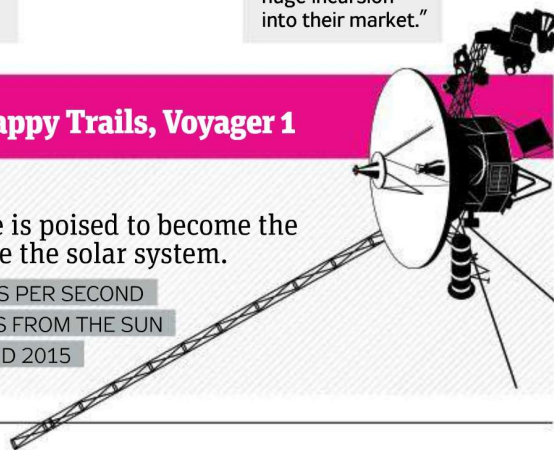
Happy Trails, Voyager 1

NASA's Voyager 1 space probe is poised to become the first man-made object to leave the solar system.

LAUNCHED: 1977 SPEED: 11 MILES PER SECOND

DISTANCE: ABOUT 11 BILLION MILES FROM THE SUN

EXIT: EXPECTED BETWEEN 2012 AND 2015



• QUICK HITS



REPURPOSED COMMODITY ➔ As electric cars gain popularity, the world is going to need a lot more lithium for batteries—and the United States already imports about half of what it requires. California-based Simbol Materials has a solution: Take the hot brine that's pumped out of the ground by geothermal power plants and extract and purify the lithium. The process also plucks manganese and zinc—two other useful minerals for battery production—from the brine, then returns the liquid to the geothermal plant to be piped underground. Simbol started commercial production last fall at a plant near the Salton Sea in Imperial Valley, Calif., which is expected to produce 550 tons per year of ultrapure lithium. Later this year, the company will break ground on another facility that will increase production to 16,000 tons per year.

• MATERIAL MIRACLES

Empty Metal

A group of scientists in California have created the world's lightest metal—100 times lighter than Styrofoam.

Working under a Defense Department program, the researchers crafted a micro-lattice of hollow nickel tubes that is 99.9 percent air. Unlike other ultralightweight materials, the metal has an ordered structure that provides strength. Stress tests confirmed that the material can be compressed until it is half as thick and then rebound to its original shape. The researchers (in a collaboration of the University of California, Irvine; HRL Laboratories; and California Institute of Technology) say the material could be used for battery electrodes or to absorb vibration or shock energy in microelectronics.

— ALEX HUTCHINSON



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David Robert, 37, first officer; 6500 flight hours. AT ABOUT 2 AM, ROBERT ENTERS THE COCKPIT AFTER A BREAK BUT LEAVES BONIN IN CONTROL.

Pierre-Cédric Bonin, 32, first officer; 2900 flight hours. THE LEAST SEASONED PILOT HELMS THE PLANE DURING MOST OF ITS FINAL MINUTES.

Captain's side stick

First officer's side stick

Marc Dubois, 58, captain; 11,000 flight hours. WITH THE CRISIS UNDER WAY, HE RETURNS TO THE COCKPIT AFTER A BREAK BUT ELECTS NOT TO TAKE CONTROL OF THE AIRCRAFT.

• WHAT WENT WRONG

The Final Minutes

AIR FRANCE 447'S COCKPIT RECORDINGS PROVIDE DEFINITIVE DETAILS OF THE CRASH. BY JEFF WISE

The crash of Air France Flight 447 has remained a mystery since it occurred over the mid-Atlantic in the early hours of June 1, 2009. As PM found in our cover story ("Anatomy of a Plane Crash," December 2009), the available data implied that the Airbus A330-200's airspeed sensors had iced up, leading to a chain of errors that cost 228 lives. Now a fuller picture has emerged with the publication in France of *Erreurs de Pilotage: Tome 5* (Altipresse, 2011) by pilot and aviation writer Jean-Pierre Otelli. The book includes the transcript of the pilots' final words—which leave little doubt that human error caused the tragedy. The transcript here (in yellow, edited for space) is followed by our analysis. The times listed in black are in coordinated universal time.

02:06:50 (Bonin) Let's go for the anti-icing system. It's better than nothing.

Flying through clouds at 35,000 feet, the pilots discuss turning on a system to try to keep ice off the sensors and flight-control surfaces. They do not. Ice reduces aerodynamic efficiency, adds weight, and, in rare cases, can cause a crash. After fixing an incorrect radar setting, Robert notices that the plane is headed into an area of unexpectedly intense storms.

02:08:03 (Robert) You can possibly pull it a little to the left.

02:08:06 (Bonin) Sorry, what?

02:08:07 (Robert) You can possibly pull it a little to the left. We're agreed that we're in manual, yeah?

Bonin banks the plane left and then asks Robert if he should turn on a feature to prevent icing in the engines. He does. Then an alarm sounds: The autopilot is switching off because the plane's external airspeed sensors, called pitot tubes, have iced over. Neither Bonin nor Robert has been trained to fly the airplane in such conditions.

02:10:06 (Bonin) I have the controls.

ABOVE: The cockpit of an Airbus A330-200.

In an attempt to avoid the storms ahead, Bonin pulls back on the side stick to put the airplane into a steep climb. A warning chime indicates that Air France 447 is leaving its planned altitude. "If he's going straight and level and he's got no airspeed [data], I don't know why he'd pull back," says Chris Nutter, an airline pilot and flight instructor. The logical thing for the co-pilots to do would be to compare airspeed data, a procedure called a cross-check. Instead, Bonin puts the airplane at risk of an aerodynamic stall. If an airplane flies too slowly or too steeply, the wings stop generating lift and the airplane starts to lose altitude. Climbing is risky because an airplane's wings generate less lift where the air is thinner.

02:10:15 (Bonin) *There's no good . . . there's no good speed indication.*

02:10:15 (Robert) *We've lost the, the, the speeds then?*
The plane is climbing at a blistering 6700 feet per minute, but its forward airspeed slows to a mere 93 knots. As the aircraft climbs, a stall alert—a synthesized voice calling "stall, stall"—sounds. AF 447's co-pilots fail to do what all pilots are trained to do when at risk of a stall—push the controls forward so the plane will level out and gain speed. In fact, Bonin inexplicably keeps pulling back on the stick.

02:10:25 (Robert) *Wing anti-ice.*

The co-pilots activate the other anti-icing system; almost immediately, one of the pitot tubes begins to work. The cockpit displays once again show valid speed information.

02:10:36 (Robert) *Descend!*

02:10:36 (Bonin) *Here we go, we're descending.*

02:10:38 (Robert) *Gently!*

Bonin keeps pulling back on the stick, but with less force. The plane reaches 223 knots as its climb becomes less steep. The stall warning falls silent. For a moment, the crew is in control of the airplane. Robert pushes a button to summon the captain.

02:10:49 (Robert) *Damn it, where is he?*

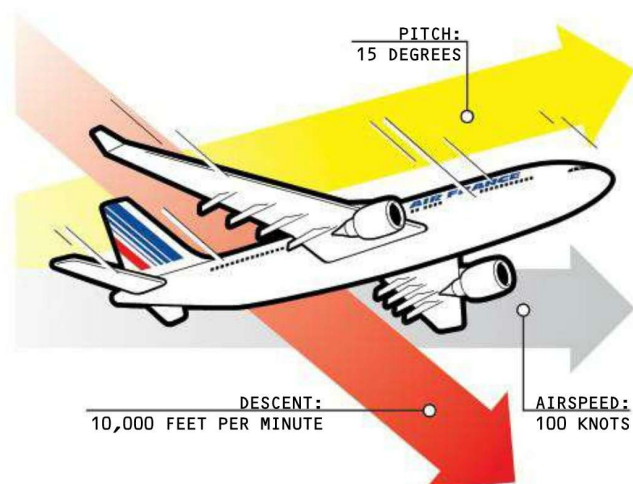
The plane is now within its acceptable altitude envelope. But Bonin again pulls back hard on the stick, raising the nose of the plane and bleeding speed. The synthesized voice again alerts them to a stall.

02:10:54 (Robert) *Damn it!*

Another pitot tube begins to function. The cockpit's avionics are now all working normally; the flight crew has all the information that they need to fly safely. The stall that occurs from this point forward is due to human error.

The Airbus is a fly-by-wire plane, meaning the control inputs from the cockpit are fed to a flight-control computer, which in turn commands actuators that move the ailerons, the rudder, and the elevator. The vast majority of the time, the computer operates within what's known as normal law, which means that the computer will not enact any control movements that would cause the plane to leave its flight envelope. The flight-control computer under normal law will not allow an aircraft to stall, aviation experts say.

But once AF 447's computer had lost its airspeed data, it disconnected the autopilot and switched from normal law to "alternate law," a regime with far fewer restrictions on what a pilot can do. Bonin may have assumed that the stall warning was spurious because he didn't realize that the plane had removed its own restrictions against stalling.



LETHAL EQUATION: AF 447 is traveling at 100 knots; the co-pilots have its nose pitched up 15 degrees. This posture does not generate enough lift, so the airliner descends 10,000 feet per minute, the air crossing the wings at a 41.5-degree angle. If the stick were released, the nose would fall, leveling out the plane and allowing it to gain forward velocity and escape the stall. But since the co-pilot holds back the side stick, the nose remains high and the plane lacks the necessary forward speed for the controls to work. The airliner maintains this position until it crashes.

02:11:03 (Bonin) *I'm in TOGA, huh?*

TOGA is an acronym for Take Off, Go Around. When a plane is taking off or aborting a landing—"going around"—it must gain both speed and altitude as efficiently as possible. At this critical phase of flight, pilots are trained to increase engine speed to the TOGA level and raise the nose to a certain pitch angle. Bonin seems to be trying to achieve the same effect: He wants to increase speed and climb away from danger. But the airplane is now in thin air at 38,000 feet, where the engines generate less thrust and the wings less lift. In these conditions, raising the nose does not result in the same angle of climb. The plane is at its maximum altitude.

02:11:21 (Robert) *We still have the engines! What the hell is happening? I don't understand what's happening.*

Even with engines at full power, with the nose pitched up, the aircraft's forward motion halts. AF 447 begins to sink toward the ocean.

Robert has no idea that, despite their conversation about descending, Bonin has continued to pull back on the side stick. Unlike the control yokes of a Boeing jetliner, the side sticks on an Airbus are "asynchronous"—that is, they move independently. "If the person in the right seat is pulling back on the side stick, the person in the left seat doesn't feel it," says David Esser, a professor of aeronautical science at Embry-Riddle Aeronautical University. "One stick doesn't move just because the other one does."

**JUNE 2009: CRASH**

("Anatomy of a Plane Crash," Popular Mechanics, December 2009) Air France Flight 447 disappears. Investigators rely on floating debris and automated maintenance messages.

JULY 2009 TO APRIL 2011: UNDERWATER SCANS

French authorities use a military submarine and autonomous underwater robots to search the seafloor for wreckage. They find it in April.

**MAY 2011: BLACK BOXES RETRIEVED**

("Plumbing the Depths of Disaster"; Tech Watch, PM, July 2011) Investigators deploy a diving robot to fetch AF 447's black boxes.

OCTOBER 2011: TRANSCRIPT OF THE COCKPIT RECORDER RELEASED

Author Jean-Pierre Otelli publishes the full transcript of the flight crew's final moments. The release sparks a debate over the way pilots are trained to react if an airplane's autopilot fails.

02:11:32 (Bonin) *Damn it, I don't have control of the plane, I don't have control of the plane at all!*

If Bonin were to let go of the controls, the nose would fall and the plane would regain forward speed. But because he is holding the stick all the way back, the nose remains high and the aircraft has little forward speed. The stall continues.

02:11:43 (Dubois) *What the hell are you doing?*

A minute and a half after the crisis began, the captain returns to the cockpit. The stall warnings are blaring. But from his seat, Dubois is unable to infer from the instrument displays why the plane is behaving as it is—because Bonin has been holding the side stick all the way back. No one has told Dubois, and he hasn't thought to ask. He does not order the less experienced co-pilot to get up so he can take control. "They were probably experiencing some pretty wild gyrations," Esser says. "In a condition like that, he might not necessarily want to make the situation worse by having one of the crew members actually disengage and stand up."

02:11:45 (Bonin) *We've lost control of the plane!*

Though the pitot tubes are now fully functional, the forward airspeed is so low that the angle-of-attack inputs are no longer accepted as valid and the stall-warning temporarily stops. This may give the pilots the impression that their situation is improving, when in fact it signals just the reverse.

02:12:14 (Robert) *What do you think? What do you think? What should we do?*

02:12:15 (Dubois) *Well, I don't know! We're going down.*

As the plane is tossed by turbulence, the captain urges Bonin to level the wings—advice that does nothing to address the main stall problem. The men briefly discuss whether they are in fact climbing or descending, before agreeing that they are indeed descending. No one mentions the word "stall."

02:13:39 (Robert) *Climb . . . climb . . . climb . . . climb . . .*

02:13:40 (Bonin) *But I've had the stick back the whole time!*

At last, Bonin reveals the crucial fact.

02:13:42 (Dubois) *No, no, no . . . Don't climb . . . no, no.*

02:13:43 (Robert) *Descend, then . . . Give me the controls . . . Give me the controls!*

Bonin yields the controls, and Robert puts the nose down. The plane descends at a precipitous angle. As it nears 2000 feet, sensors detect the fast-approaching surface and trigger a new alarm. There is no time left to build up speed by pushing the plane's nose forward into a dive. At any rate, without warning his colleagues, Bonin regains the controls and again pulls his side stick all the way back.

02:14:23 (Robert) *Damn it, we're going to crash . . .*

This can't be happening!

02:14:25 (Bonin) *But what's happening?*

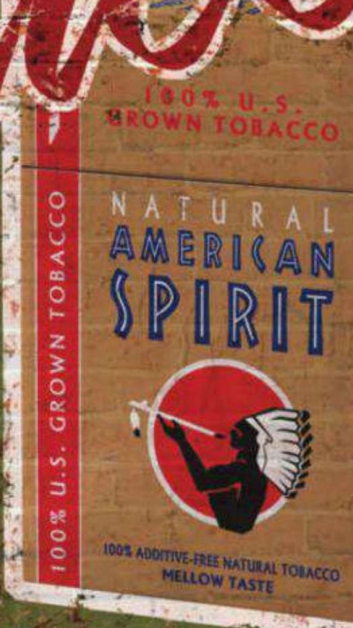
02:14:26 (Dubois) *Ten degrees of pitch . . .*

The cockpit voice recordings stop 1.4 seconds later. **PM**

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Upgrade

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Steps as fat as pogo-stick pegs help this shovel's serrated blade dig into dirt, not the soles of your boots.

The house will always have its issues. Incontinent water heaters. Slow drains. Drafty windows. But out back, the rules are different. The garden is designed to fail every fall, to lie frozen and dormant and to wait until just about now to wake up for another glorious season. Get a head start on it—sharpen your tools, take a chance on exotic seeds, and be ready, once your frozen rock of a yard thaws out, to nurture the first thrilling bursts of green shoots.

—HARRY SAWYERS

Secrets of Shovel Selection

1. In time, most shovels break at the link between the head and stick, or handle. A good tool's socket extends from the blade deep into the stick, with twin rivets to hold the connection. Six busted rakes we saw last fall had heads separated from intact fiberglass sticks—that's rivet failure.
2. Look for a closed, gusseted socket on the underside of the blade. This makes soil less likely to collect inside the tool.
3. Buy only tools with "tempered" stamped on the steel. It signals heat-treated, high-carbon, tough metal. You can't temper the low-carbon stuff.



D-handle

Midstick grip

Serrated blade

KING OF THE LOAD

↑ The prominent USA stamp on the head shows that this is one proud tool, and with good reason. The **Craftsman D-Handled Digging Shovel (\$30)** has a rugged, tempered-steel head with a deep socket riveted to its fiberglass stick, a midhandle cushion for a solid grip, a soil-slicing serrated blade edge, and a step with the footing of a ladder rung. Stomp down on the step to plunge into the earth, or just stand on it, balancing, as if it's a single stilt. Can you dig it?

Garden Labor Savers

1. Wrap tool handles with grip tape to minimize blisters and fatigue.
2. In cool, early-season weather, shroud plants in insulating skirts cut from sheets of 1.5-mm plastic. For added insulation, seek out the **Kozy-Coats Plant Protector**. Its water-filled walls help heat-loving peppers thrive all summer in cool climates.
3. Set corncobs in the yard to steer squirrels away from the garden.



HEIRLOOM CARRIER

← Craftsman Chris Hughes hammers copper burr rivets on an anvil in his Omaha, Neb., shop to make tough, multifunctional sacks like the **Artifact Bag No. 175 Tool/Garden Tote (\$155)**. He works 16-hour days to cut and stitch the rust-colored waxed canvas bags. "When you love what you're doing, it's worth it," he says. What we love is that this bag will endure for generations.

Make Your Dirt Yield a Bounty With Fresh Garden Gear

Winter's getting ready to scam, so it's a good time to gather new tools and strategize for the upcoming growing season. Collect a few of these implements of mass cultivation and you'll be ready to start tossing soil and placing seedlings in the ground just as soon as it thaws.

BY FIONA GILSENAN

DIGGER AND DAGGER

→ A multipurpose garden knife like the **GrowTech Hori-Hori (\$30)**, a Japanese tool with a name that translates as "dig-dig," can weed, plant, and cut sod. The serrated edge saws open soil sacks, and the curved steel blade scoops dirt out.



FASTENER FOR FOLIAGE

↑ Torn and flapping row covers let parasitic cabbage loopers infiltrate the veggies. Secure garden fabrics along with rope or wire with grommet-like **Lee Valley Multi-Purpose Fabric Clips (\$5 for 10)**. The teeth twist and lock to snap and stay in place.

SHARPENER DELUXE

↓ Dull pruner blades cause splintery cuts that are slow to heal. Keep 'em keen (or fix damaged edges) with the Swiss-made **Felco Istor Duplex Ultimate Sharpener** (\$47). The tool's curved blade sharpens shears, scissors, and knives. A straight grinder handles heavier blades, such as those on mowers and hoes.



BACKYARD SPYGLASS

↓ With an 18-mm lens that brings spider mites and diseased leaves up to 7x magnification, the **Carson CloseUp Monocular** (\$20 est.) can fit into a pocket or purse. The 1.7-ounce, 2½-inch-long tool also has a 472-foot field of view at 1000 yards—good for spying on birds.



THE OZARKS' FINEST HOE

→ Crafted by Missouri Mennonites, the 60-inch-handled **Rogue Hoe 575g** (\$30) is the best-selling hoe among the 40 models made by hand from tough, tempered-steel agricultural disc blades. This one is 5¼ x 2 inches, and widths range from 2½ to 10 inches. Triangular weed-clearing scuffle hoes, foot-long hand hoes, and adze-like firefighter's hoes make up the product line. "I've never held a hoe like this in my life," distributor Larry Pierce says.



Name That Seed

QUESTION:

All 10 of the seeds listed below are actual names of heirloom varieties available in the Seed Savers Exchange catalog. Honest. But only one of them grows up to be a bean. Which is it?

- summer crookneck
- turkey crow
- cream sausage
- bloody butcher
- red leprechaun
- clemson spineless
- amish deer tongue
- turk's turban
- minnesota midget
- hillbilly potato leaf

ANSWER:

The turkey crow is an heirloom bean with attractive tan flecks. Legend has it that the original seed was found in a wild turkey's crow. Gobble some up for yourself.

TOP GARDEN APPS

PUT THE DIG IN DIGITAL WITH THESE DIRTY DOWNLOADS FOR MOBILE DEVICES.



Plants vs Zombies

Mobilize peashooters, cherry bombs, gloom-shrooms, and lawnmowers to deal with the scourge of gardeners everywhere—zombies—in this quirky home-defense game.

Dirr's Tree and Shrub Finder

Tree and shrub guru Michael Dirr condensed his famed encyclopedia into an expansive, easy-to-navigate app that weighs (and costs) less than the print version.

Bugs in the Garden

Identify North American garden pests with the help of clear illustrations of common culprits as adults and larvae, then learn strategies for management and damage assessment.

ABUSIVE LAB TEST

Tape Measures

For years, Stanley's 25-foot FatMax has been the reigning champ of job-site tape measures. But I-Mark's new 16-footer, with an inked tip, can mark a measurement without a pencil. Plus, Johnson's 25-foot Stud-Squared has two sliding gauges to assist layout tasks. We checked to see how the challengers measure up to the black-and-gold standard. **BY DOUG MAHONEY**

Standout Challenge

Standout, the length a tape can extend without bending, helps hook hard-to-reach objects. We unfurled each tape five times until failure and averaged the distance.

FATMAX: (139 inches) The extra-wide and deeply concave tape displayed the structural integrity of an I-beam. It crushed the competition in this category.

I-MARK: (65 inches) The thin tape of the I-Mark meant less support. It stood out to less than half the distance of the FatMax.

STUD-SQUARED: (90 inches) Still short compared with Stanley, but the standout of 7½ feet reaches far enough to meet most measurement needs.

Weight Check

To test the strength of the tab and the lock, we hung the locked tapes from 2 x 4s and suspended 0.43-ounce washers off the tool bodies until they collapsed. All three tapes' locks failed before the tabs broke off.

FATMAX: (124 washers) The cup filled up with a total of 3 pounds, 5 ounces in washer weight—a solid showing.

I-MARK: (271 washers) This tape held a load of 7 pounds, 4 ounces. You could suspend a newborn child from this tape and still take an accurate measurement!

STUD-SQUARED: (60 washers) Talk about a limp handshake—the Stud-Squared's grip quit at under 2 pounds.

Drop Test

On a job site, tape measures are dropped as often as cigarette butts. To test the tapes' durability, we dropped them onto asphalt at 5-foot increments, up to 25 feet.

FATMAX: After falls of 5, 10, 15, 20, and 25 feet, the FatMax showed only scuff marks. We actually heard it laughing at us.

I-MARK: The 15-foot drop blew off the ink pad and damaged the tab. At 20 feet, the shell split. At 25 feet, a screw head popped out. But the I-Mark kept working.

STUD-SQUARED: At 15 feet, something broke inside. The tool rattled like a maraca. At 25 feet, the mechanism gave out completely and the tape stopped working.

BOTTOM LINE

The FatMax is the toughest, but it doesn't have bells or whistles. The full-featured Stud-Squared was also the most fragile. A tape measure is a precision tool, but it takes a licking. The key when choosing one is to balance functionality and durability.



As washers piled up, the strength of the tapes' locks grew more impressive. We realized that to conduct a truly abusive test, we'd better get a bigger bucket.

➔ Stanley FatMax (\$18)

➔ I-Mark (\$25)

➔ Johnson Stud-Squared (\$17)

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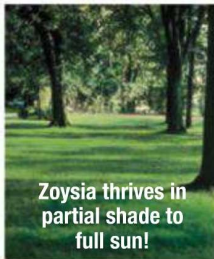
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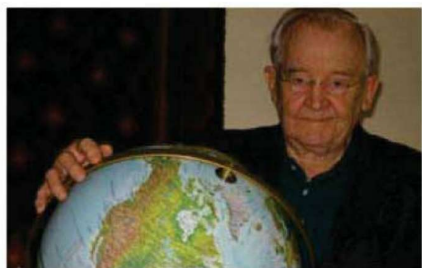
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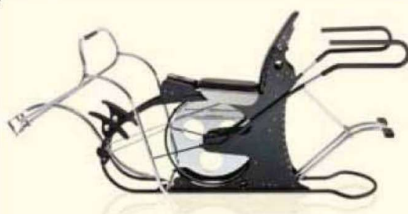


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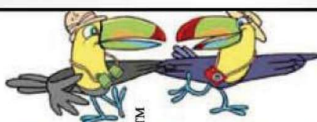


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START SAVING



Two years ago, Ferrari's 458 Italia set new standards in the midengined supercar stakes; now the Spider aims to do the same in the super-convertible market. The two-piece aluminum roof is far better than a fabric top at insulating the cockpit, but when lowered—electrically, of course—the metal panels nestle over the engine bay. Thus, for the Spider, Ferrari canned the transparent engine cover that's one of the 458's fetching details. The roof, its mechanism, and body reinforcements

add about 110 pounds to the 3300-pound coupe, but the Spider remains as sharp and quick as its closed-roof sibling. In normal motoring (if such a thing can be done in a Ferrari), there's none of the obvious structural deficiencies that plague other roadsters. We'd scratch to buy this car just to listen to the V-8's howl, but the engine also urgently hustles the Spider to stunning velocities. Objectively and subjectively, the Spider ticks all the boxes. And at about \$258,000, it should. — ANDREW ENGLISH

New Cars TEST DRIVES

4x4x4

Joining the burgeoning side-by-side market is the Kawasaki Teryx4, a surprisingly brash, powerful 0.75-liter V-twin-powered four-seat off-roader wearing the stance of a golf cart crossed with a Humvee. Kawasaki spent the past few years cruising the forums and found that owners of its popular two-seater Teryx were hacking up the cargo tray to fit a pair of bucket seats—or milk crates—for extra passengers. So the company stepped up and

joined Polaris in the four-seat side-by-side genre. The new centrifugal clutch and CVT automatic transmission are mated to a pushbutton 4WD system with locked rear and electronically locking front differentials, so the Teryx4 can shuffle up impressively steep inclines. And with its narrow width, the dirt cruiser weaves through the smallest openings. But beware of top speed: It can almost hit an unsettling, unstable 50 mph.

— ANDY DIDOROSI



2013

Subaru XV Crosstrek
\$19,000 (est.)

2012

Kawasaki Teryx4
\$13,999

CROSSING OVER

When Subaru introduced the 2012 Impreza, the former Outback Sport model was notable for its absence from Subaru's new lineup. Next fall, though, we'll see the Outback's replacement, the Impreza-

based XV Crosstrek. Designed to compete in the compact-crossover segment with vehicles like the Hyundai Tucson, Ford Escape, and Honda CR-V, the Crosstrek is essentially a lifted Impreza. It sports more ground clearance (8.6 inches) and suspension travel, yet shares the Impreza's powertrain options—a 2.0-liter boxer four with either a five-speed manual transmission or a CVT. European markets started seeing the new model in January, and we drove Euro-spec versions around Florence and Tuscany. With only 148 hp on tap and wearing snow tires for December driving, the XV wasn't thrilling despite the inspiring Mille Miglia mountain back roads, but it proved more than adequate for urban and freeway use. The XV's strength is its standard all-wheel drive, at a base price that Subaru says will be under 20 grand. But it also shares virtues of the new Impreza: improved build quality, fit and finish, fuel economy (expect mid-20s in the city and low 30s on the highway, depending on the transmission), and interior room. Those will serve it well in the lately hyper-competitive segment.

— KEVIN WILSON



SRT

All we know about the next Dodge Viper, except that it will be ludicrously fast and built in Detroit, is that it won't be a Dodge. It'll be the first vehicle of the new SRT brand and simply dubbed the SRT Viper. More SRT models will follow.

38

The mpg performance above which "you're pulling teeth to achieve," says GM's Jim Federico, product development head for small and electric cars, with regard to a vehicle's fuel efficiency.

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New Cars TEST DRIVES

THREEPEAT

BMW's new 3 Series looks a lot better in person than in pictures, but fans might be dismayed to hear that the previously standard, stirring, and silky inline six-cylinder engine has been replaced by a 2.0-liter turbocharged I-4 (the straight six, with turbocharging, remains an option). The four-cylinder's ample power (245 hp),

however, along with sophisticated exhaust sounds and greater fuel economy (36 highway mpg, estimated) ought to quash any discontent. Along with the slick six-speed manuals we love so much in BMWs, there is an eight-speed automatic available with a gear for every situation. It shifts quickly and smoothly, has steering-column paddle shifters for manual override, and downshifts to the tune of rev-matching throttle blips. A switch to electro-mechanical steering assist has done little to harm the car's famously surgical steering precision, and available adjustable shocks help adapt the car to different driving environments. Space inside has been increased by a 2-inch wheelbase stretch. And the new 3 carries a host of technological assets: active-headlight control, Bluetooth-linked apps, a color heads-up display, and auto stop-start. You can even open the trunk by performing a kicking motion beneath the rear bumper. Best of all, the new upscale interior is now worthy of the \$35,795 base price. — BARRY WINFIELD



AUTO

INTEL

3 The number of lines, according to Jaguar design chief Ian Callum, that define a car's shape. The three lines include the arc of the roof, and one from the top of each fender as the lines curve into the car's flank. Callum should know; he penned the stunning Jaguar C-X16.

560° C

The temperature at which GM bakes a coating of nitrogen and carbon onto brake rotors. The layer reduces surface rust, which lessens the chance of brake-disc shudder and increases rotor life. The new rotors are standard on a handful of Buicks and Chevys.

2012
BMW 3 Series
\$35,795

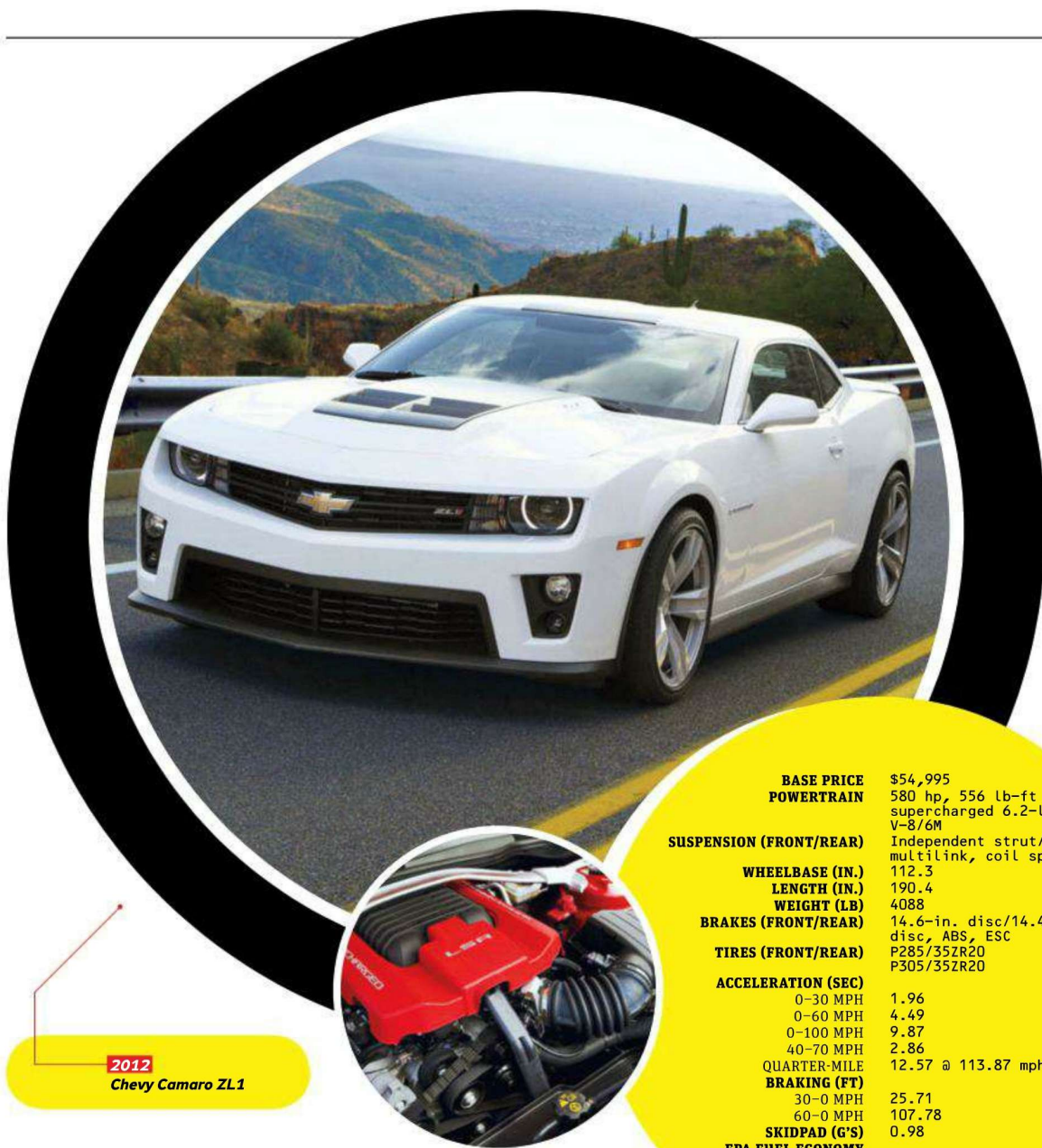
2012
Mercedes-Benz C63 AMG Coupe Black Series
\$125,000 (est.)

O UPPER-CRUST RACING

The Laguna Seca raceway was a perfect patch of curvy asphalt on which to test the 2012 Mercedes-Benz C63 AMG Coupe Black Series. With views of California's central coast, it's an automotive playground for people of means, much as the Black Series Coupe is a barely legal racing plaything for the deep-pocketed. The most powerful C-Class coupe ever built has a 517-hp V-8 with 457 lb-ft of torque. Fitted with the optional Dunlop racing slicks, this machine gallops to 60 mph in just 4.2

seconds. The car isn't a straight-line special, though. It's about getting as close to a race-car experience—tenacious grip, powerful brakes, and ferocious thrust—as possible without donning a flame-retardant suit. A set of deep bucket seats, selectable traction control that steps in only when you're headed into the weeds, incredible steering feedback, and a lusty exhaust note combine for a fantastic out-of-the-box—but ritzy—\$125,000 track toy. Check the next page for a more reasonably priced option. — BEN WOJDYLA





2012

Chevy Camaro ZL1

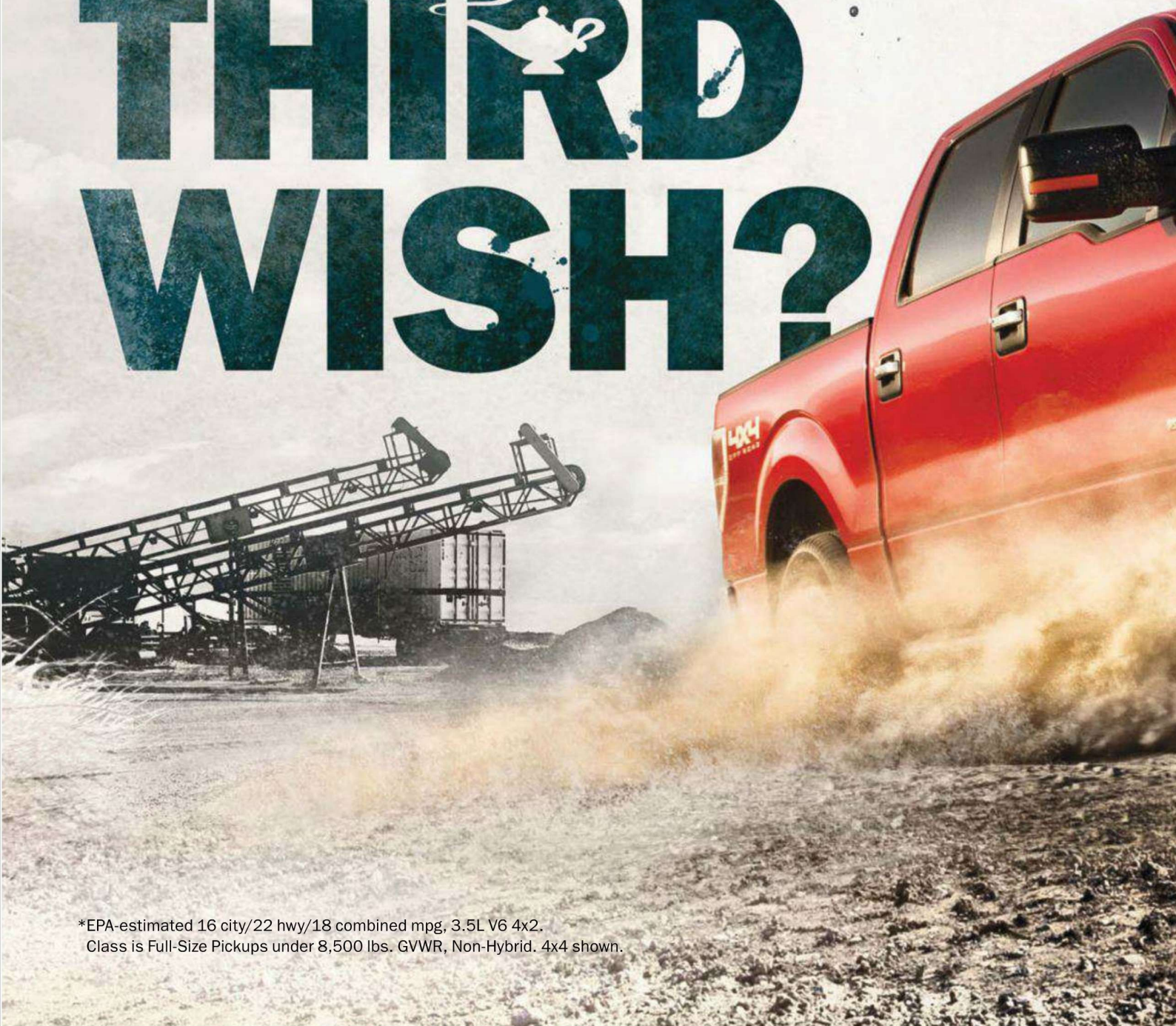
BASE PRICE	\$54,995
POWERTRAIN	580 hp, 556 lb-ft supercharged 6.2-liter V-8/6M
SUSPENSION (FRONT/REAR)	Independent strut/multilink, coil springs
WHEELBASE (IN.)	112.3
LENGTH (IN.)	190.4
WEIGHT (LB)	4088
BRAKES (FRONT/REAR)	14.6-in. disc/14.4-in. disc, ABS, ESC
TIRES (FRONT/REAR)	P285/35ZR20 P305/35ZR20
ACCELERATION (SEC)	
0-30 MPH	1.96
0-60 MPH	4.49
0-100 MPH	9.87
40-70 MPH	2.86
QUARTER-MILE	12.57 @ 113.87 mph
BRAKING (FT)	
30-0 MPH	25.71
60-0 MPH	107.78
SKIDPAD (G'S)	0.98
EPA FUEL ECONOMY	
CITY	14
HIGHWAY	22

AMERICAN BADASS

The ZL1's headline-grabbing figure is 580 hp, which, admittedly, is a completely addictive amount of giddyup to have under your right foot. But focusing on the power overlooks the fact that the ZL1 is probably the first Camaro in history to turn better than it sprints. For this top-end version of the Camaro, GM engineers added not just an engine supercharger, but also numerous chassis upgrades. The key bits are four adjustable shocks that automatically firm up to lend a rather stunning combination of precise feel and predictable handling. Here's how we know: Approaching a gentle but very fast right-hand kink at Arizona's Inde Motorsports Ranch, we cut the corner just a touch too tight, dropping the right-side wheels into a hole next to the track surface. At 100 mph, that's the sort of mistake that can turn ugly instantly. The ZL1, however, bounced out of the hole, immediately regained composure, and carried on as if we'd nailed the turn. Thanks, partner. With coolers for nearly every mechanical system, dinner-plate-size brakes, and grippy tires, the ZL1 stayed sharp through repeated laps. A heads-up display projects a tachometer and shift lights onto the windshield so your eyes stay where they're needed—on the road. Chevy also installed a new steering wheel and shifter, with far more comfortable contours than before. Speaking of comfort, those shocks also soften, so the on-road ride is firm but passable. There's only one thing we'd change: the exhaust sound. The Camaro's burble is a far cry from a Malibu's, but it should have a more righteous bark. The ZL1 deserves to swagger. — LARRY WEBSTER

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WITH SMARTPHONE INTEGRATION AND INTERNET CONNECTIVITY, AUTOMAKERS ARE IN UNFAMILIAR TERRITORY—WITHOUT A MAP.
BY ANDREW DEL-COLLE

Our phones and our cars are colliding. Despite the National Transportation Safety Board's recent call for a nationwide ban on in-car cell-phone use, car buyers are increasingly demanding smartphone-style connectivity. And carmakers are scrambling to provide interactive systems that harness or imitate the fea-

tures of popular handsets. These so-called infotainment systems, such as Ford's Sync and Toyota's Entune, have voice control and Internet connectivity, and they can run apps such as Pandora. In a world where quality engineering can be bought even in entry-level cars, infotainment systems are increasingly seen as a differentiator—but they have become a high-tech headache for automakers.

"It's kind of a mess," says Roger Lancot, a senior analyst at technology research firm Strategy Analytics. "Because all of these systems are proprietary, it's expensive to deploy content app by app. They are also all brand-new, and they all work differently, so you have usability issues and glitches galore."

THE TECHNOLOGY TRAP

Arguably one of the most advanced infotainment systems on the market is Sync with MyFord Touch, available

as an option on all of Ford's consumer models. Its capabilities are formidable: It has touch-sensitive, capacitive buttons; it can understand complex voice commands, make hands-free calls, read your text messages to you, run Pandora from connected smartphone devices, and give you turn-by-turn navigation. But for all of its sophistication, MyFord Touch has been criticized for being slow, cluttered, and confusing. The system is a big reason why Ford fell from fifth place to 23rd in J.D. Power's 2011 Initial Quality Study. Now Ford is sending out more than 300,000 USB drives to update it. Systems like MyFord Touch tap into the cellular-connection and data-processing power of smartphones for many of their functions, but deliver user interfaces that pale in comparison to those of the phones. All of which raises the question: Why don't automakers just use the phone operating systems in the first place?

PHONING IT IN

As it turns out, there are systems in development that can, to a degree, port your smartphone's UI to your vehicle's screen. One such technology is Nokia's MirrorLink. Once the phone is connected to the car, MirrorLink essentially turns your dashboard display into a slightly modified version of your smartphone screen—as long as the phone and the vehicle display are MirrorLink-capable. MirrorLink has some big backers, including Toyota, General Motors, Nokia, and LG and could start appearing in select vehicles and phones in the U.S. in the next couple of years, Lancot says. But then again, it may not, since one company notably absent from the MirrorLink supporter list is Apple, the most influential smartphone-maker in the world.

But even if smartphones are superior to most factory-installed infotainment systems, that doesn't necessarily mean they are an ideal replacement. Andy Gryc is the auto-



motive product manager at QNX, a software company that has provided the code for almost 30 million vehicles on the road. “You have an expectation of how an application behaves on your phone, with a small display and a ton of RAM,” he says. “You’re used to scrolling around through menus and pinching and zooming and all these things, and when you take that same display and replicate it in the car, the experience isn’t the same.”

Systems such as MirrorLink also could exacerbate the nettlesome problem of driver distraction. When a carmaker creates its own interface, it can control the driving experience. But if the screen in the vehicle is essentially a pass-through to somebody else’s software, that raises a big red liability flag. So automakers will want to tightly control which apps and functions are allowed.

Still, using the phone’s interface could free carmakers from some of the fast-paced burdens of software development. Vehicles generally take years to design, while smartphone operating systems and apps can be updated every few months.

CUE THE FUTURE

If MirrorLink is the answer, it’s only a temporary one. According to Mike Hichme, engineering manager for Cadillac’s Cue system, no car can be fully dependent on a phone. “[MirrorLink] is a feature; that’s not the solution,” he says. Automakers still need to design radio, HVAC, and other basic vehicle controls. No car company is willing to just hand off fundamental parts of the driving experience to a phone.

Plus, it turns out that auto interfaces may be learning some smartphone tricks after all. Hichme’s Cue system, set to premiere in three models later this year, can run HTML5, the same software language behind powerful Web apps such as Gmail. HTML5 should make it easier for developers to create apps that run across all platforms—which may ultimately neutralize the power struggle between smartphone and car. Still, HTML5 doesn’t mean an app free-for-all. No one thinks playing Angry Birds in the car is wise.

Unfortunately for automakers, none of this makes the decisions any easier. If a car is just beginning the production process, there’s no one answer and no knowing where the industry will be three or four years from now. “It’s just painful to have to make these decisions when things are changing too damn fast,” Lanctot says. **PM**

FIAT MULTIAIR

ENGINE
OF THE
MONTH



Solenoids (in red on top of the valve) control the flow of pressurized oil to cycle the intake valves.

MINI OIL PUMPS WORK THE VALVES IN FIAT'S INGENIOUS SYSTEM.

Engines are like

people: The harder they work, the more air they need to breathe. When an engine is revved high, like when accelerating on the highway, its valves must open wide and for long durations. Conversely, at idle, that engine requires just a trickle of air to operate. Variable valve timing and lift systems continuously alter the way a valve operates, depending on engine speed and load, to increase fuel efficiency and power. These systems are becoming more common, but Fiat’s Multiair is the most novel. It operates the intake valves with a unique system: Rather than using the cam lobe to press open the valve, the lobe pushes on the plunger of a tiny oil

pump. The resultant pressure accumulates in a thimble-size chamber that feeds a computer-controlled solenoid (the valve “conductor”). When the solenoid is open, the oil pressure flows to the top of the valve, forcing it to open. The engine computer directs the solenoid and can vary the timing (when the valve opens in relation to the piston’s movement), duration, and lift (how far the valve opens). With Multiair, the tiny 1.4-liter engine of the Fiat 500 produces a gutsy 101 hp and a healthy amount of low-rpm torque. Also, since the system is simple and compact, it’s not an expensive add-on. Expect Multiair to spread through Fiat’s—and Chrysler’s—lineup. — LARRY WEBSTER

Anatomy of Big Air

> BY JEREMY REPANICH
> PHOTOGRAPHS BY ADAM MORAN

O

lympic snowboarding gold medalist Kelly Clark made history in 2011. At January's Winter X Games, she uncorked the first 1080—three full rotations—executed by a woman in competition. At the 29th Burton U.S. Open Snowboarding Championship in March, she hit the trick again. Before winning her fifth Open title, Clark did a 900 for our cameras; the trick lasts 2 seconds and was captured in 23 frames (only 13 are shown here). Three decades of advances in half-pipe engineering, physical training, and board design have allowed snowboarders to fly higher and spin more quickly. With Clark's assistance, we break down the mechanics behind snowboarding's new heights.

900°

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HEART RATE
EXCEEDS 180 BPM.

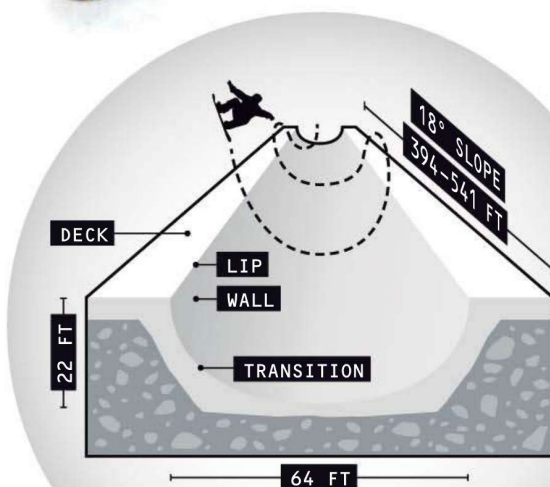
3

720°

CLARK LANDS AT 45 DEGREES
WITH UP TO 600 POUNDS OF
FORCE—MORE THAN FOUR
TIMES HER BODY WEIGHT.

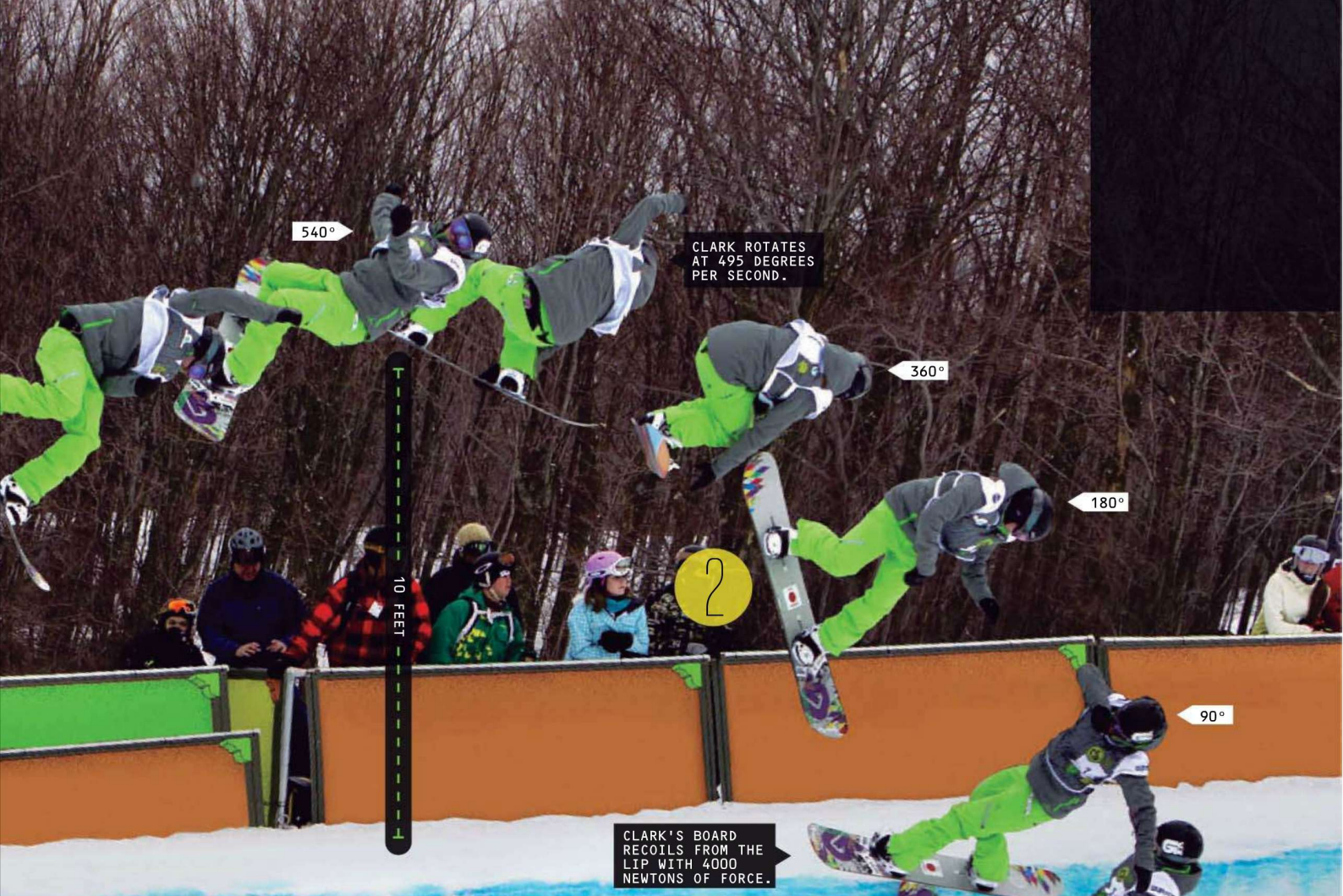
THE BOARD

Once just crude wooden planks, snowboards have evolved into precisely engineered pieces of equipment. The core is composed of small wooden strips arranged to improve strength and flexibility. Because wood is strongest when bending with the grain, the strips near each end run parallel to the board's length, adding spring. In the center, the grain runs perpendicular so it flexes as the rider leans forward and back. Fiberglass and carbon fiber add strength, and a Teflon-infused epoxy reduces friction. At an event, techs hone a board's edges and bake wax into it overnight: On cold, dry days, when snow is icy, a hard wax is used; on warm, wet days, a softer wax applied with texture prevents suction. "The board base is absorbent," Clark says. "The more it's waxed, the faster it gets."



THE PIPE

The original half-pipes, built in the late '70s, were little more than creek beds that riders modified by shoveling snow. But with the invention of the Pipe Dragon—an excavator with a curved arm—in 1990, carving uniform pipes became easier. As riders pushed for bigger air, the excavators grew to cut larger pipes, progressing from 10- to 12- to 18-foot-high walls and then 22 feet, introduced in 2006. "The pitch of the 22-foot pipe is steeper, which allows you to carry more speed—it's enabled the progression we've seen in snowboarding," Clark says. "I don't want to go near an 18-foot pipe anymore."



1: APPROACH

In the pipe, riders can travel up to 40 mph, but they have to fight the forces that sap speed. As Clark moves along the arc in the transition from flat bottom to vertical wall, centripetal force pushes her down. Harnessing that force adds speed, but if she buckles, Clark's body absorbs kinetic energy and slows down. As she approaches the pipe's transition—where centripetal force is the highest—Clark pumps her legs. This stiffens her body and causes her to exert more force on the ground, which, according to Newton's third law of motion, pushes back and boosts her speed.

2: LAUNCH & FLIGHT

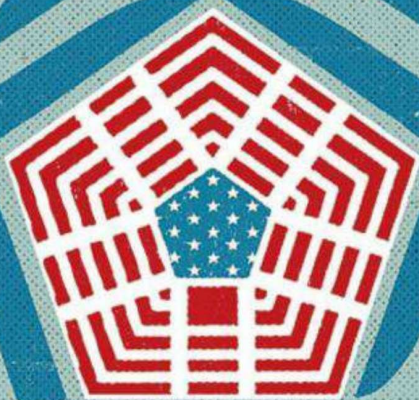
"One of the biggest misconceptions is people liken it to a vertical jump," says Jon Turnbull, the winter performance program manager at the New Zealand Academy of Sport. If snowboarders jumped like basketball players, they'd fly away from the wall and toward the center of the pipe, instead of up above the lip. Clark generates height by rotating her body as she reaches the lip, which creates vertical velocity. Once in the air, she pulls her arms close to her body to increase rotation and spin in a fluid motion. "The more compact I am," she says, "the faster I spin."

3: LANDING

Clark spots her landing two-thirds through a trick. When landing, she must "pull the chute—you make yourself as big as you can to slow your rotation," she says. To maintain speed into the next trick, she reenters the pipe as high on the wall as possible while angling her board down the pipe to take advantage of its 18-degree pitch. When she lands, Clark must keep her body rigid; flexing her knees would absorb energy and decrease her speed. "She's maintaining her gravitational potential energy from a body of flight and changing it to kinetic energy," Turnbull says. **PM**

The Winning Way to Trim the Pentagon

> BY JOE PAPPALARDO
> ILLUSTRATION BY DAN PAGE



1 MAINTAIN AIR SUPERIORITY

Every conceivable geopolitical and strategic wartime scenario begins with ownership of the airspace over the theater of operations. But enemy radar, warplanes, and anti-aircraft missiles are improving. It is wise to make the most of the already steep investments in sophisticated airplanes by fielding enough of them.

RECOMMENDATIONS:

Trim the number of Navy and Air Force versions of the F-35 by 25 percent.



F-35 Lightning II variants are tempting targets for deep cuts. But they will be able to evade sophisticated radar systems and bring unparalleled sensor fusion to the battlefield—attributes that are critical in modern war. The White House will likely restructure the program; we advise against delaying development because it will alienate international customers. We say trim F-35 purchases, but do not drop the numbers to fewer than 1320 aircraft for the Air Force and 280 for the Navy. And don't be deterred by the subsequent increase in price per plane.

FINANCIAL IMPACT: This move saves about \$6 billion over a decade, even after aircraft are purchased to replace the cut F-35s.

T

HERE'S A BATTLE RAGING IN WASHINGTON, D.C., over the direction of the military. There are two key factors pushing and pulling the debate: emerging threats that demand responses and a \$15 trillion deficit that must be reduced. These conflicting imperatives present great risks, but also represent a historic opportunity.

America could come out of this process with a leaner, more flexible military—but only if cuts are made in tandem with a transformation in how the military fights. These changes involve the Pentagon's core missions of nuclear deterrence, regime change, humanitarian aid, and pinpoint airstrikes. To transform means making smart investments as well as cuts. We based the following POPULAR MECHANICS plan on the capabilities of possible foes. Alas, some of the problematic programs singled out for elimination by politicians and policy wonks are the best hedges against these growing threats. Our focus is on frontline hardware and strategy. (We'll let others recommend how deeply to cut troop pay and retirement benefits.)

Funding for overseas deployments totaled \$162 billion in 2010. With that in mind, the PM plan was designed to increase the flexibility of deployments and decrease their cost.

TAMING THE U.S. DEFENSE BUDGET REQUIRES CHANGING THE WAY AMERICA FIGHTS.

Preserve every F-35B.

The F-35B can take off and land vertically, transforming any flattop amphibious troop carrier into a formidable stealth aircraft carrier. Amphibious-ready groups need advanced-strike aircraft that don't require aircraft carriers; keep the 300 originally planned.

FINANCIAL IMPACT:

There's no doubt F-35Bs are expensive, at \$150 million per plane with steep operations costs. But their capability is hard to replace if they are delayed or canceled. The White House wants to delay development—we say keep the programs moving.

2 PREP TO FIGHT 1.5 WARS

President Barack Obama and

Defense Secretary Leon Panetta are arguing for an end to the post-Cold War standard of maintaining a military that can fight two major ground wars at the same time. Secretaries of defense under presidents Bill Clinton and George W. Bush tried to do the same thing and failed. We agree that it's time to end that baseline of preparation. In the current environment, fighting one ground war while conducting sustained airstrikes and special operations missions in another theater is enough.

RECOMMENDATIONS:

Trim active-duty Army personnel from 570,000 to 450,000.

Easing back from two-war preparation diminishes

demand for ground forces. Our cuts go deeper than those expected from Panetta, mostly because adopting sea basing (below) reduces the need for land facilities. Unlike the White House, we would preserve the Marine Corps at current strength.

FINANCIAL IMPACT:

About \$30 billion saved over 10 years.

**Delay/cancel next-gen ground vehicles.**

The Army's inventory of ground vehicles, swollen from recent conflicts, is sufficient.

FINANCIAL IMPACT:

Delaying the Ground Combat Vehicle program saves \$7 billion and canceling the Joint Light Tactical Vehicle, \$10.9 billion. Use some of the savings to upgrade Bradley Fighting Vehicles and up-armored Humvees.

3 EMBRACE SEA BASING

More than half the world's population lives within 120 miles of a coastline—a statistic that defines future battle-grounds. The concept of sea basing avoids land bases in favor of deploying all forces from ships. This decreases the footprint of a military operation and enables the president to adjust the deployment based on need—making entering and exiting military campaigns



easier. A sea base can be set up in foreign waters without permission. It can also be resupplied—meaning no more diplomatic quid pro quos for border crossings or airspace access.

RECOMMENDATIONS:**Build transport ships.**

Pentagon officials have stated that sea basing requires transport ships on the U.S. coasts to reach anywhere in the world in 11 days. Today's ships are too slow; a new 14-ship flotilla of fast aircraft- and cargo-carrying vessels is required.

FINANCIAL IMPACT:

An investment of about \$14 billion will be needed, but it's better to adapt existing commercial designs for the military than to rent retrofitted fleets from contractors.

Retire the USS George Washington (CVN-73).

It may seem counterintuitive to advocate sea basing and cut carrier battle groups to a total of 10. But with more flattops launching helicopters, unmanned aircraft, and stealth F-35Bs, fewer carriers will be required.

FINANCIAL IMPACT:

The *George Washington* is about to be overhauled; retiring it (and its air wing) instead saves about \$7 billion over 10 years.

4 ADOPT A NUCLEAR DYAD

It's important to possess nuclear weapons as more global players develop them. But America has too many, and too many delivery systems: 14 Ohio-class submarines, 94 bombers, and 450 intercontinental ballistic missiles. This triad was designed to defeat the Soviet arsenal; the Russian stockpile is now greatly reduced. Cut one leg and keep new missiles on alert in efficient ways.

RECOMMENDATIONS:**Retire all 14 nuclear-missile submarines.**

ICBMs offer the quickest response, and bombers attack with precision and surprise. The Cold War calculus that makes submarines valuable nuke launchers is based on their ability to hide and independently launch a second strike during a now unlikely extended nuclear exchange. Ignoring the howls of nuclear strategists, we point out that survivability is no longer as vital.

FINANCIAL IMPACT:

According to the Congressional Budget Office, cutting the sub replacement program will save \$99 billion, with another \$15 billion saved in research.

**Rebase nuclear ICBMs.**

The Air Force keeps 450 ICBMs in three vast fields that extend over tens of thousands of square miles—a herculean effort of maintenance and security. A series of consolidated but widely spaced nuclear-missile facilities could replace today's sprawling, 1960s-era ICBM fields. The new model: the bases that house multistage interceptor rockets for the Missile Defense Agency.

FINANCIAL IMPACT:

The tens of billions of dollars spent to establish new nuclear bases and missiles will pay for itself over the years in reduced staff, retired silos, and avoided maintenance costs. These systems will be 70 years old when they reach the end of their service lives in 2030. The Obama administration has already dodged a decision on a replacement; it is time to commit to a new way. **PM**



A graphic with a blue background and a torn paper effect at the top. The text 'POPULAR MECHANICS' is in a bold, black, sans-serif font. Below it, 'PRESENTS' is in a smaller, white, sans-serif font. The main title 'KNOWING YOUR STUFF' is in a large, bold, black, sans-serif font, with 'YOUR' in a smaller, white, sans-serif font. The background has a blue gradient and some white starburst or spark-like graphics.

**FOR SAVING TIME, MONEY, AND
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BY THE EDITORS**

PHOTOGRAPHS BY
DWIGHT ESCHLIMAN

**PROP STYLING BY
MEGAN CAPONETTO**

MORE!



In one of our very first issues, back in 1902, we told the story of an Illinois schoolboy named Mark Richards, who built an automobile for himself. By saving money from his after-school job blacking stoves, Richards cobbled together enough parts to assemble a runabout that rolled on four skinny

tires and was powered by a single-cylinder engine. "I had no knowledge of the principles and practice of gasoline engine construction," Richards said, "yet I not only managed to make it but to build the transmission mechanism, friction clutch, spark-timing mechanism, body running gear, etc., even doing the necessary blacksmithing . . . I stuck to the job and am gratified with the result."

If Mark Richards were alive today, he would love the story of Bob Dullam, a sculptor in Kalamazoo, Mich., who received one of our 2009 Backyard Genius Awards for building a replica of the Tumbler Batmobile. Dullam fabricated a steel chassis and laid on body plates made of epoxy reinforced with fiberglass matte, then dropped in a 350 Chevy V-8 and slapped on 44-inch-wide Super Swamper tires. Why did Dullam spend \$50,000 on his beast? "I like Batman," he says, "and the only way to get this car was to build it myself."

The impulse to tinker, to putter, to do it yourself instead of buying it or paying someone to do it for you—Richards and Dullam share that mindset with millions of do-it-yourselfers. Sometimes economic necessity drives this impulse, and other times the motivation has no price tag—it's the pride and freedom that come with self-reliance.

In 2012, as POPULAR MECHANICS celebrates 110 years in publication, self-reliance remains a guiding principle of the magazine. While PM's long-standing slogan "Written So You Can Understand It" no longer appears on the cover, the magazine's mission remains the same: Use plain language to present stories about how things work—whether those things are internal combustion engines, supercomputers, or spacecraft—as well as how to make and fix things yourself.

Indeed, POPULAR MECHANICS has depicted and fostered DIY for more than a century, which is why we chose it as the subject of this month's cover story.

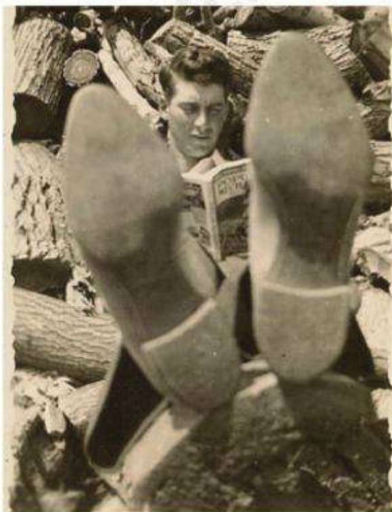
By the time PM debuted in 1902, the Second Industrial Revolution was at full gallop and DIY was embedded in the American grain. Railroads had punched all the way to the West Coast, factories were gobbling up farmland, and the country was changing from a rural nation into an urban one. The year after Mark Richards built his runabout, Henry Ford and David Dunbar Buick, a couple of hardcore DIYers, jumped into the burgeoning automobile business. In the decades straddling the 19th and 20th centuries, while the first great car craze swept the nation, another significant trend emerged: Between 1890 and 1930, home ownership tripled and the American house itself became a project.

To guide the masses, the early issues of POPULAR MECHANICS were aimed at the initiated. Many readers were part of the rising class of mechanical professionals, people who knew how to fashion a miter joint, operate a lathe, and handle a drill press. The magazine's Shop Notes offered advice on "How to Temper Springs" and "Punching Structural Steel for Locomotive Tenders," while Amateur Mechanics taught younger readers how to make such things as a dovetail-joint puzzle. On a parallel track, by 1930 Sears, Roebuck & Co. had a building-materials catalog offering "everything you need to build, remodel, modernize or repair your house."

As America emerged from the Great Depression, the first golden age of PM's DIY coverage dawned with the introduction of the Solving Home Problems and The Craftsman sections. The former offered little tips (put a sponge-rubber ball on the end of a coat hook to keep hats from slipping off), while the latter showed how to tackle big jobs ("Outdoor Fireplace of Poured Concrete").

After a lull during World War II, DIY exploded along with the postwar economic boom. Suburban housing developments, typified by Levittowns near Philadelphia and on Long Island, provided a vast opportunity for DIYers. As soon as people moved into a cookie-cutter Levittown house, they started making modifications—adding a porch, expanding the garage, building a dormer. Technology was there to lend a hand with the introduction of lightweight portable power tools and the popularization of such convenient materials as drywall, Formica, and latex paint. And while Detroit kept cranking out ever more exotic cars, gearheads from the East Coast to California were out in the garage using yesteryear's models to concoct their very own one-of-a-

kind kandy-kolored tangerine-flake streamline babies. PM responded in 1962 by introducing one of our longest-running and most avidly



FLOYD ALBERT MARTIN OF JEFFERSON, IOWA, READS PLANS FOR BUILDING A ROLLING CHAIR LONGUE IN THE JULY 1938 ISSUE. WATCH OUT, WOODPILE!

THE AGES OF
DIY

read sections of the magazine, Saturday Mechanic.

Beginning in 1971, Appliance Clinic helped readers deal with a deluge of electronic devices and household appliances; a decade later, computers were added to the mix with the advent of Software Monitor. A California kid named Steve Jobs, who grew up building Heathkit electronics projects, would later say that his boyhood forays into DIY “gave a tremendous level of self-confidence, that through exploration and learning one could understand seemingly very complex things.” After dropping out of college, Jobs retreated to his parents’ garage with a buddy named Steve Wozniak to modify the first personal computer, the Altair 8800. You know the rest of that story.

Jobs would later say that one of the “bibles” of his generation was *The Whole Earth Catalog*, a DIY project begun in 1968 by Stewart Brand, who put issues together with a couple of friends in Menlo Park, Calif., using an IBM Selectric typewriter and a Polaroid MP-3 camera. While the catalog appealed primarily to the counterculture, and PM stuck to the mainstream, both publications celebrated self-reliance. “It was all about empowering individuals,” Brand says. “The people who read it were interested in starting over from scratch.”

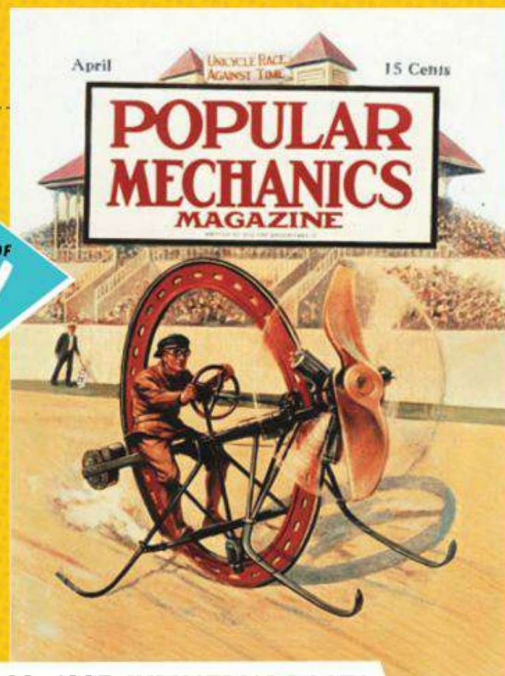
Although the DIY mindset seemed to fade in the 1980s and ’90s with the rise of the digital era, it returned in a new form at the start of the 21st century. While computer modding has roots in the late 1970s, its analog cousin—the maker movement—sprang to life in the early 2000s. Happily for PM, we are now in the midst of a hands-on creative resurgence. “What’s going on today is fantastic,” Brand says. “Maker Faire, DIYbio in Boston, tech schemers and dreamers, garage biotech people writing genetic code—basically what you’ve got now is a tech-friendly generation of young people who are aware they can mess with the hardware as much as the software.”

One of the hottest of the many DIY hotbeds is Brooklyn, N.Y. In the Boerum Hill neighborhood, half a dozen young co-workers gathered recently in the offices of MakerBot Industries, which has shipped more than 6500 of its desktop 3D printers to customers all over the world. Bre Pettis, the company’s 39-year-old co-founder and CEO, was regaling the group with tales of childhood adventures with an uncle in Boston who used to get up at 4 am to cruise the city’s garbage-truck routes, scavenging stuff he would fix and reuse or sell at weekend flea markets. “Together we built a bicycle for me from spare parts,” Pettis said. “It was a dirt bike, and we painted it black. At the end I had this aha! moment—this bike is mine, and I can fix it if it breaks. Mystery was replaced by pure satisfaction. It’s very powerful when you’re 6 years old and realize you can fix anything.”

Thanks to DIY’s open-source ethos, he added, people today can make almost anything using off-the-shelf modules and parts, backed by a community willing to share designs, ideas, and computer code. “We started this company because we wanted to have a machine that can make anything,” Pettis said, “putting the power of manufacturing in people’s hands.”

MakerBot’s 3D printer, for all its wizardry, is not really something new. Rather, like *POPULAR MECHANICS* today, the invention is a contemporary manifestation of a very old tradition. It’s the latest link in an unbroken DIY chain that goes as far back as Ben Franklin’s stove, Mark Richards’s runabout, Henry Ford’s Model T, Stewart Brand’s catalog, and Bob Dullam’s Batmobile. It’s a safe bet that someone is out in the garage or down in the basement right now, working on the next big thing. Tinkering, puttering, hacking. Doing it himself.

THE AGES OF
DIY



1902–1925: INDUSTRIAL ROOTS

PM founding editor H.H. Windsor writes for an audience of tradesmen and farmers already familiar with machining, wiring, and woodworking. Doing it yourself is essential to making a living. Shop Notes and Amateur Mechanics sections show how to hone these skills in stories such as May 1908’s tutorial on fixing a machine’s broken flywheel, or a December 1917 project, “Electric Bolt Lock Made from Bell Ringer.”

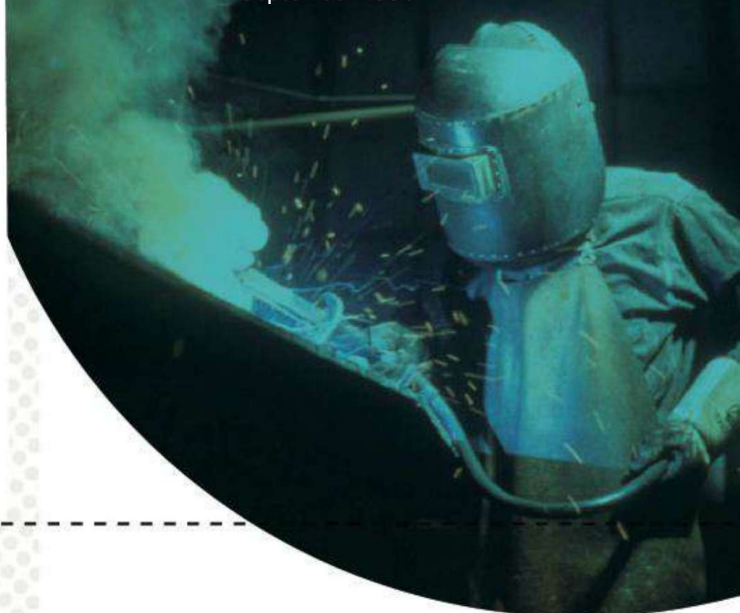
1902

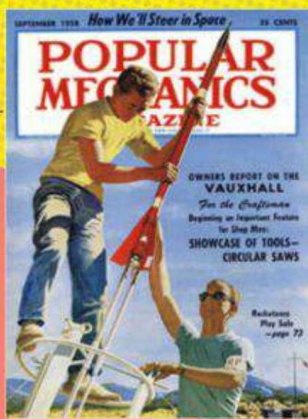
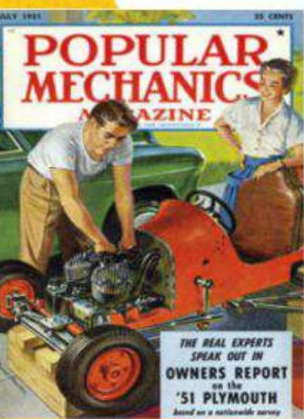
1925

1925–1940: THE SHOP COMES HOME



POPULAR MECHANICS covers promise bold breakthroughs, but the magazine’s how-to pages grapple with the hard realities of the Great Depression. Tips emphasize reuse of items like inner tubes and crankcases. American workers apply trade skills to tasks at home, as projects explain how to vermin-proof an icebox drain, in May 1927, or how to hook a tray onto a beach umbrella, in September 1936.





1985-2005: THE AGE OF SWEAT EQUITY



DIY remains satisfying as a creative enterprise, but it gains allure as a way to maximize an investment. An April 1987 feature simply titled "Doing It Yourself" demonstrates how a weekend upgrade can translate into dollars saved. Hardware stores grow larger, and the range of options they offer a homeowner expands. POPULAR MECHANICS begins running regular tool tests to explain how to choose a hammer—not just any hammer, but the best hammer money can buy.

1940-1965: RISE OF THE NOVICE

The postwar surge in new housing makes DIY a fundamental part of owning a home and living the American dream. POPULAR MECHANICS' Solving Home Problems section tackles leaky faucets, busted clocks, and sticky drawers. Projects retain a sense of thrift—empty 35-mm film canisters become picnic saltshakers in May 1947. The homeowner steadily rises to prosperity. By July 1958, a typical story shows how to entertain guests with a new backyard smoker (made from a cleaned-out oil drum).

1940

1965

1985

2005

1965-1985: THE WEEKEND-PROJECT ERA



Americans continue to put down roots in new suburbs. As tastes and housing technology evolve, problem-solving changes from homespun to sophisticated. The magazine turns its DIY advice to maintaining new machines with the September 1971 debut of the Appliance Clinic. DIY becomes an outlet for fun and creative expression in the Weekend Workshop section, where detailed home-build stories like March 1972's "A Backyard Storage Building That Isn't an Eyesore" define the times.

2005-PRESENT: THE MAKER REVOLUTION



As some sectors of domestic manufacturing erode, the DIY zeitgeist shifts again. The act of making anything—plywood shelves, plumbing-pipe lamps, backyard roller coasters—is respected and celebrated in stories such as POPULAR MECHANICS' annual Backyard Genius franchise and September 2009's "Ruggedize Your Own Tech." Technology and communication offer new ways to share creations with like-minded communities such as those featured in May 2011's "DIY Underground." But the abstract nature of the digital age also stokes an enduring need to create an object that can be held, used, taken apart, and put back together.



Great in the garage.

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★ **Brace for Boards**

Our September 1948 issue showed how to store an ironing board upright in a closet by mounting a towel rack to a wall. The board's tip slips up under the chest-high rack. It's still a good idea. At the right height, a rack (or a rig made of steel pipe fittings) could support brooms or lumber.

★ **Find a Key, Fast**

File a notch in a frequently used key's top to locate it without looking through the whole set.
— April 1984

★ **Copper Wire Flashlight Stand**

To set up a simple worklight, coil 12-gauge copper wire around a flashlight's barrel and twist the rest into a base.
— March 2011

★ **Got That Wrench?**

On band saws, router tables, or other shop equipment that requires a wrench to make routine adjustments, we advised in July 1952: Press the wrench into a lump of weather-stripping putty and stick the putty on the side of the shop tool. The wrench will be easy to locate for quick changes of bits and blades.

★ **Pinhole Lens**

The August 1955 issue told a farsighted person to punch a pinhole in cardboard and peer through it to read small type. It still does the trick!

★ **Jar Pumps Up Radio Tunes**

"Transistor radios produce a deeper, more melodious tone when placed speaker-down on top of an open fruit jar." This worked in February 1961. And it works today for an iPhone.

★ **Fortify Studs**

Nail 2 x 4 blocking between studs when framing walls, we suggested in November 1948. The boards provide sturdy mounting bases for heavy pictures or recessed medicine cabinets. Record the positions upon installation.



◀ **FIT BOTTLE CAPS ONTO C-CLAMP PADS TO MAKE A MARK-FREE CLAMP.** — JANUARY 1963



• MARCH •

Hole in One

Enlarged screw holes can be quickly repaired, we said in March 1972, by filling the hole with a wooden golf tee. Use a hacksaw to saw the tee flush with the wood's surface, then sand and finish.



- ◊ ADD SAND TO FLOOR PAINT, A POUND PER GALLON, FOR A SKID-FREE COAT. — FEBRUARY 2010
- ◊ MIST WATER AT A SPARK PLUG AS A VEHICLE IDLES. VISIBLE ARCS SHOW VOLTAGE LEAKS. — FEBRUARY 1995
- ◄ FILL EMPTY SHOTGUN SHELLS WITH MELTED WAX AND A WICK TO MAKE CAMPSITE CANDLES. — FEBRUARY 1961

★ Dry Up Paint Drool

Punch holes in a paint-can rim with a 4d finish nail. This helps paint along the rim drain into the can. — January 1991

★ Get a Handle on a Broken Tool

"Replacing a shovel handle is one of those disappearing rural skills that shows basic mechanical competence—just as wrapping duct tape around a broken handle denotes the opposite," the May 2007 issue said. Getting a wood handle's grain direction right ensures the strength of a replacement handle. Mount the new handle so that the oval rings of wood grain run up and down the sides of the handle relative to the blade. Handles break when the tool is strained along those ovals. A look down the blade toward the face of the handle should reveal only straight, parallel lines of wood grain.

★ Slow-Leak Test

A tire tip from December 1935: To locate a pinhole leak in a bike tire's inner tube, hold it under water and watch for bubbles.

★ Floating Frames

Our August 1965 issue recommended taping small blocks of Styrofoam to eyeglasses' bows, or legs, while fishing or boating. If the glasses go overboard, they'll float.

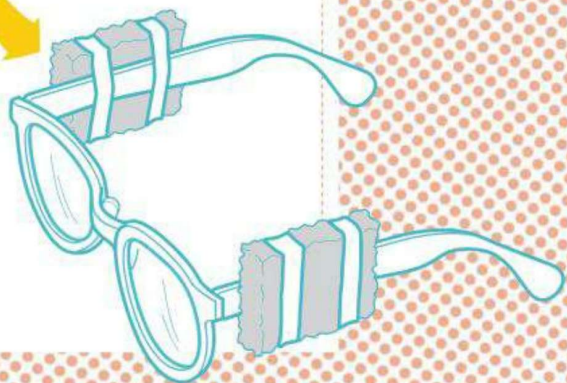
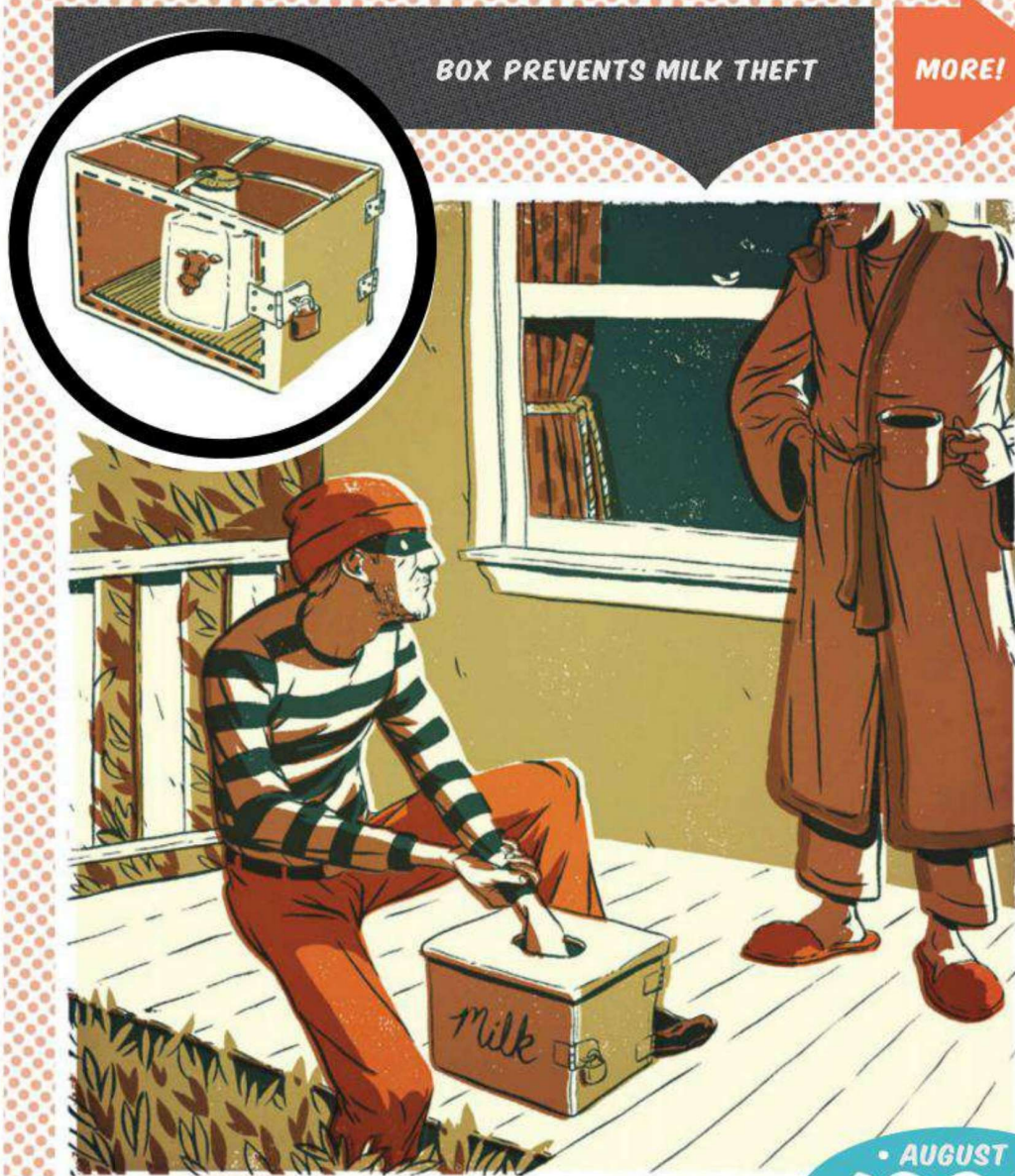


DIAGRAM ILLUSTRATIONS BY DOGO

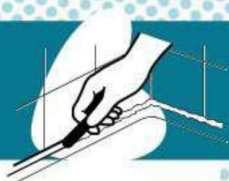


BOX PREVENTS MILK THEFT

MORE!

• AUGUST •
1934

Depression-era milk thieves met their match with the bandit-proof box we showed bolted to a porch in August 1934. A hole in the top permits the bottle to be set inside, and four strips of spring brass prevent its removal. The owner unlocks a panel to access the milk. Home-security technology evolved in PM's pages, from safes made of spare tires to whole-house diagrams on burglar deterrence.

QUICK
FIX

- PICK UP SLIVERS OF BROKEN GLASS WITH WADS OF MOIST COTTON. — MARCH 1949
- USE AN ICE-CREAM-BAR STICK TO SMOOTH CAULK IN CORNERS. — FEBRUARY 1963
- NEST A BRICK CHISEL IN BROOM BRISTLES TO CONTAIN DUST FROM A STRIKE. — APRIL 1984

★ **Improvised Slides for Heavy Drawers**

The January 1970 issue showed how to reuse a bleach bottle to ease action on a heavily laden drawer. Cut $\frac{3}{4}$ x 2-inch strips from a clean, empty bottle. Heat the plastic and fold its long side into a $\frac{1}{4}$ -inch lip. Mount the strips at the bottom front corners of the drawer frame. The drawer slides on the strips, reducing friction.

★ **Keyhole Guide**

"A particularly useful device for people who are forced to stay out late at night" appeared in the September 1914 issue: the key guide. A V-shaped strip of metal affixed to the door tapers to a point just above the keyhole. The key's tip slides along the metal to find the keyhole opening. "This simple device should prove very useful in places where it is impossible to illuminate the keyhole."

★ **Sandbag Clamps**

Use sandbags to help glue down irregular shapes, such as veneers on uneven surfaces. — March 1983

★ **Block That Door**

To stop a door from swinging while working on its lock or knob hardware, our November 1948 issue suggested this: Notch a block of wood to fit the edge of the door. Set the block on the floor, wedge the notch onto the door's edge, and step on the block.

★ **Closet-Rod Stop**

"The last suit or garment generally takes a beating in a crowded closet." To prevent this, wrap rubber bands around the rod a few inches from each end to form ridged stops for the wire hangers. — January 1959

GLOVEFUL O' TOOLS

MORE!

An old glove can become a miniature tool belt with a few modifications, according to our January 1949 issue. Cut a slit in the cuff of the glove so a belt can pass through it. Then snip off the fingertips and thumb tip. Worn on a hip, the open fingertips can conveniently carry pliers and large screwdrivers.

• JANUARY •
1949

★ **Roof-Rack Mount**

"Transporting a sheet of thin building material can be tricky, as the sheets flutter and flap when carried flat on a car's roof rack," we said in July 1982. The solution: Set a 2 x 4 on the roof rack, running the length of the car. Secure the sheets to the rack's side rails. Twist the 2 x 4 so that it

stands on its narrower edge. The 2 x 4 will bow the sheets so they're rigid enough to withstand the wind.

★ **No Sliding on Siding**

"Jars of bolts and screws that are placed on shelves near power tools often are shaken off the shelf because of vibration from the machinery,"

according to our July 1946 issue. Clapboard siding, then and now, is beveled. The end that would face downward on a home's exterior is wider than the end facing upward. Nail the siding to the shelf with the flat face down and the wide end at the shelf's edge. This tilts the shelf toward the wall.

- To make a clip-anywhere camera tripod, braze bolts onto the clamp body and fit tripod heads onto the bolts. — *May 1951*
- Use a C-clamp as a handle for a heavy bucket or drum. — *March 1961*
- To move large furniture, weld casters onto C-clamps and clip the clamps to the furniture legs. — *March 1949*
- When removing a brake caliper, first use a C-clamp to pinch off the brake hose to minimize fluid loss. — *June 2001*

C-Clamp Bonanza

1957

• FEBRUARY •

Tighten a C-clamp onto a ladder rail, our February 1957 issue said, to keep a hammer “safely at hand” when working up high.



★ Chuck-Key Clip

To keep from losing track of a drill-press chuck key, mount a clothespin to the press and clip the key in the pin's jaws. — December 1955

★ Two-Step Pushstick

“When you make a table saw's pushstick—and there should always be one handy—cut two notches instead of one in the end.” The stepped stick end has one notch cut at ½-inch depth and a second notch cut to ¼ inch. Flipping the stick allows either thickness of stock to be pushed safely and securely toward the blade. — March 1962

★ Doorknobs Access Garbage Cans

Trash-can lids still pose a problem that PM tried to solve in December 1946, when we suggested mounting two discarded doorknobs on each face of the garbage-can lid. The knobs act both as a handle and a hanger. Grab the knob on top to remove the lid, and use the knob on the underside to hook it over the can's edge. This leaves both hands free to deal with trash.

★ Soap Speeds Screws

Wood screws turn more easily in tight-fitting holes when threads are rubbed with a slightly wet bar of soap. — September 1957

★ Erudite Craftsmen Reuse Old Binders

Fasten the metal portion of a three-ring binder to the top of a stepladder, we said in August 1972. Mount the binder so the rings face downward. Tools with holes drilled in their handles can be stored and replaced. When the ladder is to be moved, snap shut the rings and tools will be securely held. The rings can also be used to hang cleaned brushes to dry.

★ Stop Suffering From Plywood Blowout

To prevent splintered edges as a saw blade exits plywood, press masking tape onto the back side of the cut, we said in May



1982. "The cut won't be absolutely clean, but it will be better than without tape."

★ Lick Envelopes With Potatoes

For readers burdened by correspondence, our November 1948 issue offered "one way to avoid the unpleasant task of licking postage stamps." The trick: Moisten the stamps using a potato cut in half. The water in the potato activates the adhesive. Stamps today often adhere like stickers, but a spare spud can still be used to moisten a pile of envelope flaps.

★ Gloves Pad Ladders

Fit cotton gloves atop ladder rails to prevent scratches where the ladder rests against paint or masonry. — March 1959

★ Tire Sled Slides Heavy Stone

Haul a heavy boulder out of a yard, our June 1951 issue suggested, by using an old tire to make a sled. Use a bolt and nut to fasten two thick lumber planks in a cross shape and wedge them inside the tire. Drill a hole in one plank near the end. Loop and fasten a chain through the plank and around the tire. Roll the stone onto the planks; hook the chain to a tractor or a truck to tow away the sled. The stone rides above grade in the tire opening while the tire edge drags on the ground.

★ Thirst: The Other Mother of Invention

To quickly make a bottle opener, drive a nail into a board so the head stands proud ½ inch. Bend the shank and grab the bottle by the nailhead. — March 1966



- ◀ GROOVE AN AX HEAD TO AID CHOPPING. — AUGUST 1924
- ◊ POLISH METAL WITH A CLOTH DUSTED IN CHALK. — APRIL 1957
- ◊ SLIT A RADIATOR HOSE END TO EASE REMOVAL. — MAY 1990

STOUT-STRAP STOPPER

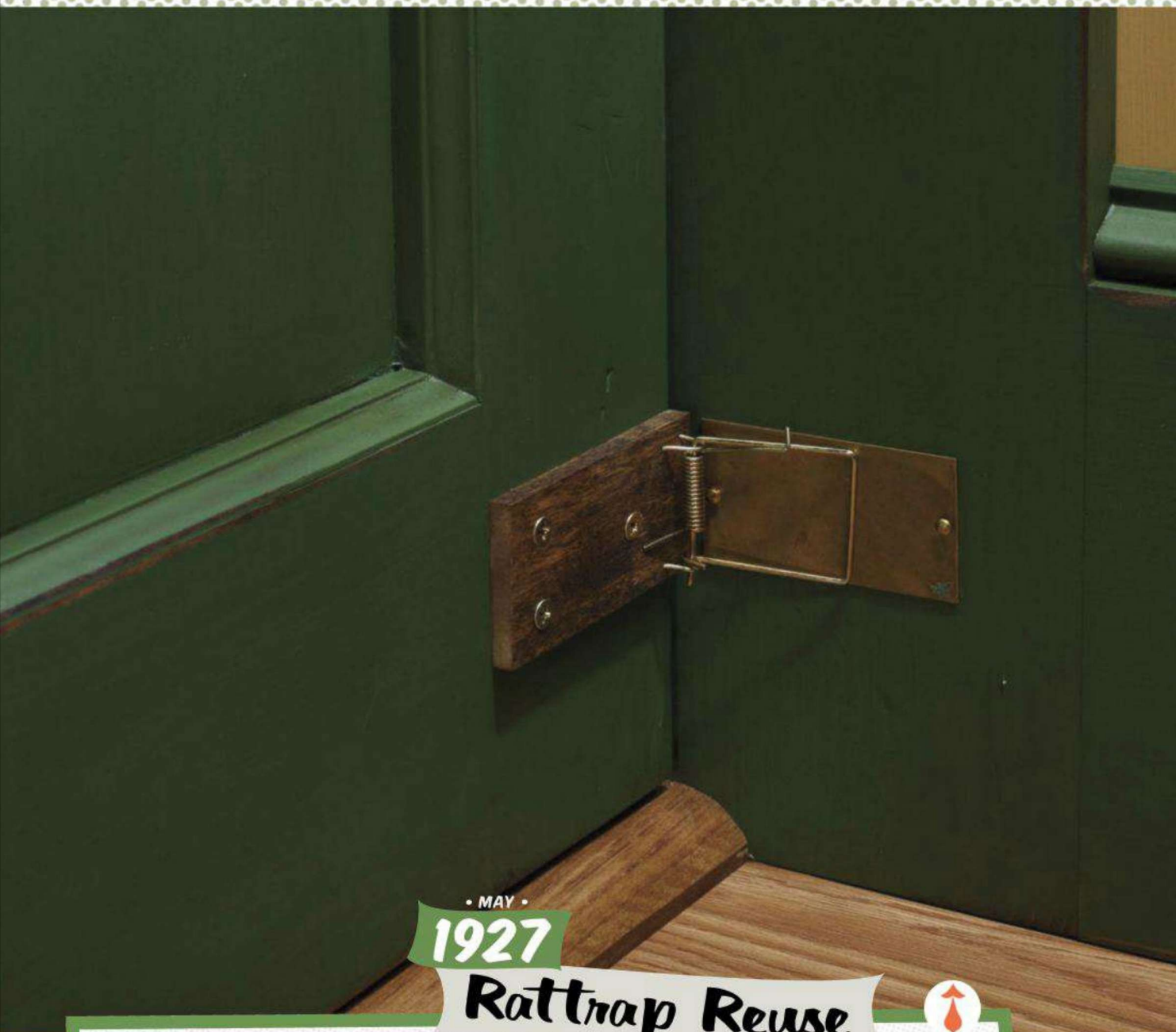
MORE!



On an incline, a hand truck can roll backward and cause an injury, our February 1938 issue cautioned. Reduce the risk by mounting stout fabric straps on the truck's frame above the wheels. Move forward and the straps flap out of the way. Go backward and the straps tuck under the wheels to arrest motion.



- USE A SINK PLUNGER TO PULL OUT A STUCK DRAWER WITH A MISSING KNOB. — FEBRUARY 1966
- STACK BRICKS IN A CYLINDRICAL SHAPE TO MAKE A VENTED LEAF-BURNING BIN. — APRIL 1947
- ◄ STROKE A PENCIL OVER A STICKY KEY'S SURFACE TO LUBRICATE IT AND THE LOCK. — JULY 1926



• MAY •

1927

Rattrap Reuse



- ➔ Screw a trap to a trailer to hold a warning flag when towing large objects. — August 1932
- ➔ Mount several traps to a workshop wall to make a handy rack for gloves, notes, and receipts. — May 1954
- ➔ Anchor one end of a long tape measure by clipping the tape in a nailed-down trap. — January 1938
- ➔ Retrieve dropped, unreachable tools with a trap dangling on a string. Hit the tool with the bait pan. — July 1961

"We had a door that we wanted to keep closed, and not having any suitable ready-made device at hand, we made one from a spring rattrap," we said in our May 1927 issue. Saw off the bait end of the trap and screw the remaining part to the door casing. Protect the adjacent surface with a piece of tin. "This door closer works perfectly, and is cheap."

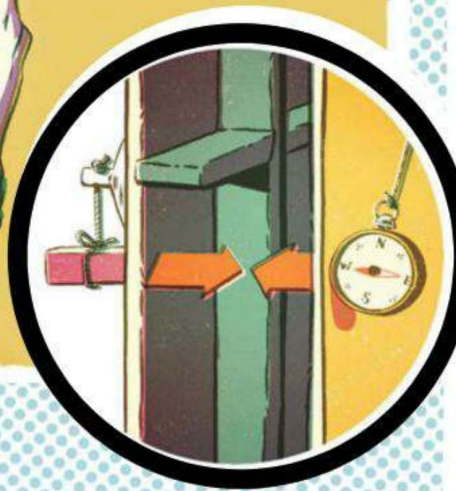
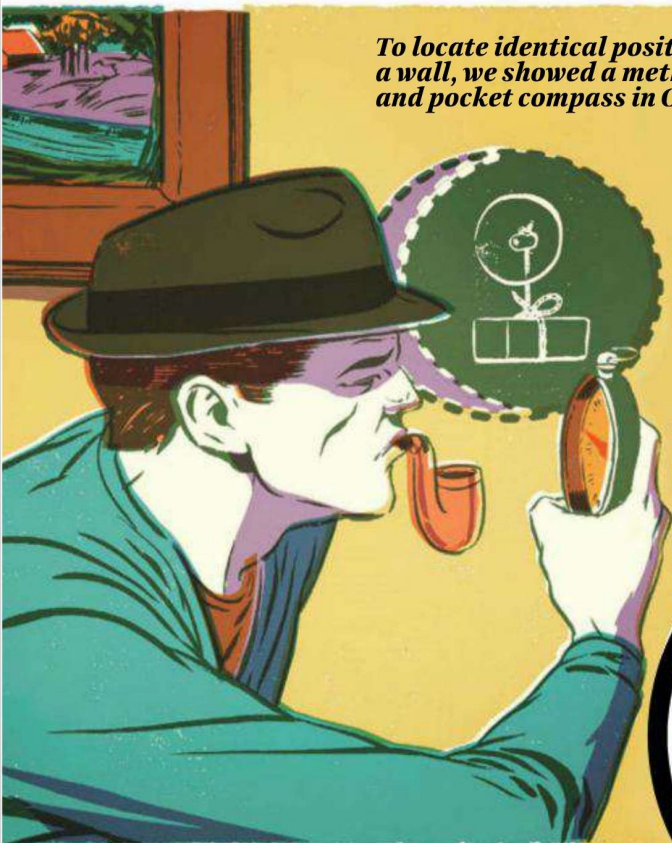
QUICK
FIX

- CUT DISCS FROM WINE CORKS TO MAKE SLIDING FEET FOR CHAIRS. — MARCH 1963
- DRILL GUIDE HOLES IN A BLOCK TO STOP SCREWDRIVER SLIPS. — APRIL 1957
- SWAP FAT SAFETY PINS FOR MACHINES' MISSING COTTER PINS. — SEPTEMBER 1917

INTERIOR ORIENTATION

To locate identical positions on opposite sides of a wall, we showed a method using a bar magnet and pocket compass in October 1943. The magnet, attached to a suction cup, holds the position on one side of the wall. On the other side, a compass points to the magnet so the spot can be marked.

• OCTOBER •
1943

★ **How to Haul a Saw**

It's tricky to protect a large push-style handsaw when transporting it along with sawhorses. Our November 1983 issue solved the problem. Cut a saw slot in each end of the sawhorse cross-piece. When finished using the saw, drop it in the slot.

★ **Bucket Stabilizer**

To prevent a bucket or other round container from sliding

around on top of a bench while scouring the inside, our March 1934 issue said, lay the bucket on its side and wedge auto tire tubes beneath the curved exterior. To update the tip, use bicycle inner tubes.

★ **New Life for a Broken Broom**

A broken broomstick is just another new tool. In March 1981, we showed how to shape a broken handle into

a spike to make a dibble for digging holes for bulbs and seeds. A broken shovel with a D-handle also works well. In July 1946, the broomstick entered the game room as a dart rack: Plane an 8-inch length of broomstick so that it can be fastened to a backboard. Drill holes for the darts at a 45-degree angle $\frac{1}{8}$ inch in diameter, $\frac{1}{2}$ inch deep, spaced 1 inch apart on center.

★ **A Chisel Manicure**

Because a dull wood chisel produces slipshod work, use a method we suggested in June 1948 to test the tool for adequate sharpness. Push the chisel cutting edge gently over the top of a thumbnail. If it slides without catching, the chisel needs to be sharpened.

★ **Crescent as Caliper**

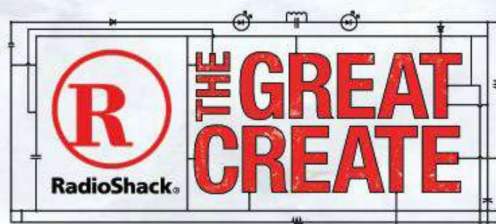
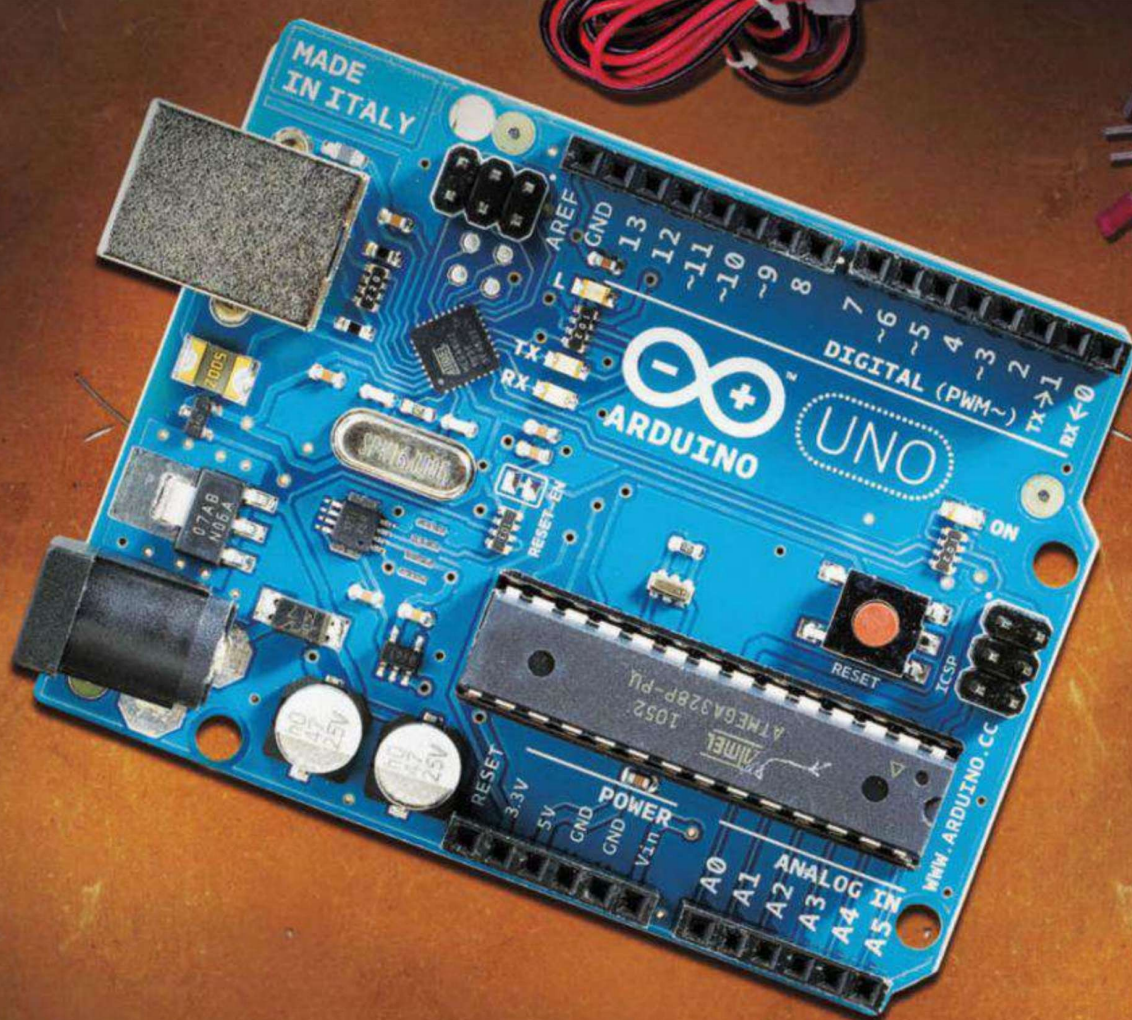
To measure a drill bit to bore a pilot hole for a nut and bolt assembly, our August 1965 issue recommended using an adjustable wrench as a crude caliper to determine the bolt's diameter. Then match the wrench jaw's reading with a corresponding drill-bit diameter.

★ **Baste the Brakes**

When replacing brake fluid, it's necessary to flush out the system. Don't do that by reusing the old muddy brown fluid in the reservoir, we said in November 1992. Use a turkey baster to siphon the excess fluid from the reservoir, then add a little clean fluid to flush out the reservoir. And don't use that baster on poultry ever again.

★ **Sandpaper Saver**

To unclog sandpaper, rinse it in lacquer thinner, then buff the paper with a wire brush. — September 1954



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QUICK
FIX

- ◀ HANG A FUNNEL ON THE WALL TO EASILY DISPENSE A SPOOL OF TWINE. — AUGUST 1939
- LINE GARDEN COLD FRAMES WITH ALUMINUM FOIL TO CONCENTRATE HEAT. — APRIL 1964
- STORE A WET PAINTBRUSH OVERNIGHT IN TIGHTLY WRAPPED WAX PAPER. — APRIL 1957

★ **Better Paper Cuts**

We shared the secret to making neat cuts in large spools of paper in our March 1969 issue. With the spool standing vertically, unfurl the length of paper planned for use. Begin the cut a few inches from the top, slicing downward. The uncut section supports the sheet so it doesn't droop and tear. Snip off the top portion to finish the cut.

★ **Fuel-Spray Stifler**

Servicing a fuel-injection system opens up lines with pressures that can top 60 psi, we warned in August 2002. "That's enough to spray atomized gasoline across the shop." Here's how to protect your eyes: Wrap a screwdriver shank in a shop towel and use the tip to depress the Schrader valve stem in the fuel rail's diagnostic fitting.

★ **How to Silence a Clanking Chain**

To prevent a chain from rattling, weave a rope in between the links, we said in June 1916. Arrange the rope so that it threads only in spaces between the links.

★ **Defend the Home With a Putty Knife**

To protect painted walls and other delicate surfaces when using a hammer to pull nails, wedge a putty knife beneath the tool's claw, our August 1954 issue recommended.



• MARCH •

1910

Bolt + Nuts = Wrench!

"If in need of a wrench and one is not at hand, take a large bolt and run on two nuts, allowing a space between them to fit over the nut to be turned," we said in March 1910. "This will make a serviceable wrench, a substitute that will prove very beneficial in case of an emergency."

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• NOVEMBER •

1948

5 Uses for Hose

Six-inch garden-hose scraps can hold hand tools, we noted in November 1948. Cut the hose to length with a small tab at the top to take a wall-mounting screw. "Using garden hose for this purpose is especially convenient for the man who does not want to build a cabinet."



QUICK
FIX

- ◀ USE A PUNCTURED COFFEE CAN TO SHIELD A BARE BASEMENT BULB. — JANUARY 1950
- PULL HEADLESS FINISH NAILS TIP-FIRST TO AVOID SPLITTING LUMBER. — APRIL 1963
- SAND A SQUEEGEE'S RUBBER TO RESTORE ITS WORN EDGE. — APRIL 1957

POOL-TABLE-TILT FIX

MORE!

• NOVEMBER •
1937

To level a billiard table or a piece of machinery in all directions at once, we advised in November 1937, use a slab of flat glass and a ball bearing. "You can note the low spot by observing in which direction the ball moves." Shim the legs to level the surface in all directions.

★ **Stop Dropping Those Drawers**

"No doubt you have pulled a drawer all the way out and—c-r-r-a-s-h!" Our December 1961 issue had a solution for drawers prone to pulling free of dressers: Pull the drawer out as far as safely possible and paint a red stripe on each rail next to the cabinet face. Paint a black stripe 2 inches closer to the front of the drawer. Pull the drawer out no farther than the black mark and you'll avoid spilling its load.

★ **Old Bleach Jug Helps Green Thumb**

Punch holes in the cap of a clean, empty bleach jug to make a garden watering can. — December 1962

★ **Glove Pads Make Polishing Easy**

A pair of homemade mitts simplify and speed up the job of polishing a car, we said in July 1952. Stitch several thicknesses of terry-cloth toweling or cheesecloth to a pair of cloth work gloves. Use one glove to apply the polish and the other to remove the excess. Wash the mitts in soapy hot water.

★ **Ladder Scraper for Muddy Boots**

Our July 1958 issue had a tip for working safely on round ladder rungs in a muddy yard: Mount a length of bar stock low on the ladder, then scrape mud off boot soles before climbing. Mount another rigid bar near the top of the ladder and you can scrape goop off putty knives and trowels.

- ➔ Use hose lengths to protect a child's hands from swing-set chains. — May 1933
- ➔ Wrap a hose length in sandpaper to abrade concave and convex profiles. — February 1972
- ➔ Cut a hose strip to cushion the back of a push saw. Press the blade into the work. — January 1954
- ➔ Wrap a cold chisel or a star drill in a hose length to make a shock-absorbing grip. — March 1937

• APRIL •

1921

Campsite Cabinet

"The camp hanger shown is easily made by attaching hooks to an old leather belt," we recommended in April 1921. For hardware, hang S-hooks or bend stout wire through holes punched in the leather. "The hanger will be found quite a convenience for clothing and utensils used around the camp."



QUICK FIX



- TO HIDE A SCRATCH IN WALNUT FINISH, RUB IT WITH A SLICED WALNUT. — OCTOBER 1954
- ◀ GIVE A HAMMER CLAW A FRESH BITE WITH A HACKSAW CUT. — NOVEMBER 1957
- ROLL TIRE CHAINS IN BURLAP TO STOP TANGLES AND NOISE. — NOVEMBER 1948

★ Bottle Caps Drain Potted Plants

"When pebbles or ceramic fragments are not available for use as drainage material in the bottom of a flowerpot," we said in November 1956, "metal bottle caps make a good substitute." Place them with the crimped edge down to cover the entire bottom of the container.

★ News on Windows

Our April 2003 issue offered a glass-cleaning classic: Use old newspapers to clean dirty windows. Save paper towels.

★ Padlock Hardware

A strap hinge taken from a barn door makes a hasp for a padlock. Remove the hinge pin and separate the halves. Fasten one hinge half to a doorframe, with the wide end of the strap mounted through to the frame, and the narrow end projecting outward. Fasten the other hinge half to the door itself, in the same orientation, so the holes align on the narrow, projecting ends. Insert the lock so its bar spans the holes. — November 1938

★ Milk Carton Ignites Charcoal

Use a cardboard milk carton to start charcoal for a grill, we said in May 1960. Cut off the top and stack the coals inside. The wax-coated carton will produce a hot flame around them.

★ Training Wheels for the Shop

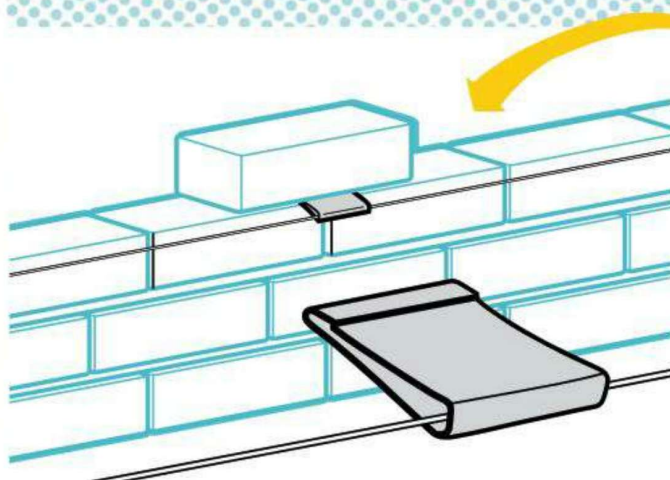
Don't toss out training wheels when a child moves on to a bigger bike. Mount the wheels to bench saws and other heavy shop machinery. Attach the wheels above the floor and tilt the machines to move them around. — April 1972

MORE!



Rack for Heels

"Looking for a simple rack for your wife's shoes? You won't find a more practical one," we said in January 1961. Drill holes to fit the heels, and mount the panel so it stands proud of the closet wall.



★ Mason's Helper

"A matchbook held by a brick takes the sag out of a mason's line." The matchbook suspends the line, keeping it the right distance from the top course so it doesn't interfere with striking the mortared joint. — July 1962

★ Keep Matches Dry

To waterproof matches, dip them in melted paraffin wax. — April 1916

QUICK
FIX

- ◀ START BONFIRES WITH AN OIL-SOAKED CORNCOB WEDGED IN A PIPE. — JUNE 1949
- MARK A GARDEN TROWEL HANDLE TO MAKE A SOIL-DEPTH GAUGE. — JUNE 1954
- USE OLIVE OIL TO LOOSEN PAPER ADHERED TO WOOD VARNISH. — JANUARY 1950

Regrets...

we've had a few



• SEPTEMBER •
1926

Shirt-Shredding Washing Machine
“Facing an accumulation of soiled clothing that would have cost at least \$10 if done at the laundry,” a reader reasoned that his outboard motor could agitate suds. Mounted on a barrel divided by a screen, the rig worked, he claimed—for 10 cents. The clothing’s condition afterward was not mentioned. — September 1926

FILTHY PLAYPEN

“When a playpen is needed and none is at hand, just take a kitchen or other small table, turn it upside down, and stretch cloth around the outside of the legs.” The tip suggests padding the table’s underside with an old comforter, but doesn’t mention clearing out the cobwebs and chewing gum first. — February 1938

RATTRAPS MURDER TURTLES

“Spring-type rattraps are an effective means of disposing of turtles which menace game fish in a pond or lake.” An illustration shows a turtle about to bite a chicken head in a trap mounted to a post set in shallow water. Sorry, turtles. Our apologies to the chickens too. — June 1948

TRUNK LID MAKES BOSS AWNING

“One home craftsman used the trunk lid of an old sedan to make a serviceable and inexpensive canopy for the back door of his home.” The trunk was dressed up, at least, with wrought-steel supports. — June 1954

★ Five Auto Fixes

The October 2009 issue gave “Get-Home-at-Any-Cost” tips for roadside catastrophes, beginning with a leak in the radiator. Crack a raw egg into the radiator filler cap (not the overflow tank). The egg white will plug the hole—for a while. To fill the radiator back up: Top it off with water, diet soda, tea, or any other sugar-free liquid. To fix a punctured gas tank: Stuff a wedge from a bar of soap into the hole. It’ll last long enough to get you into town. Oil pan punctured by a stone? Whittle a plug from a twig and hammer it into the hole. But now you’re low on oil. To fill the crankcase, add a quart of water. Really. The oil-pump pickup is not on the exact bottom—the remaining oil will float on top of the water.

★ Shovel Weeder

For weeding in the cracks of concrete, our June 1938 issue said, “a shovel is handy... it enables you to do the work quickly and prevents sore fingers.” Good luck finding a spare shovel today. Those weeds can now be uprooted from tight cracks with an old putty knife or a painter’s five-in-one tool.

★ Fixing a Hole

In the January 1963 issue, we recommended using a sliver snapped from a toothpaste tube to fill a stripped-out screw hole. Screw threads bite into the metal. With today’s plastic tubes, a toothpick works better. But the essence of the tip remains: Implements of oral hygiene can fill cavities. **PM**

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THE SPRING THAT REVOLUTIONIZED NASCAR

by Larry Webster

photograph by Charles Masters

TRAVIS ROAD IS ONE OF A HUNDRED DIRT LANES THAT ROAD CREWS in this part of southeastern Michigan haven't gotten around to paving. On this late November day, a cold, steady rain has enlarged the potholes into craters that bounce my car as I approach a large, nondescript metal building. It's the kind of obscure facility that's sprinkled across the older suburbs of Michigan, Ohio, and the rest of the car-building belt of the Midwest. GM's Milford Proving Ground is 10 miles to the north, the border of Detroit 25 miles to the south. A small sign outside says PSI SPRINGS.

Inside is the guy everyone says I need to talk to, Steve Bown. He is tall, with wide shoulders and noticeably broad hands that make him look more like a tight end than someone who devotes his waking hours to the minute details of valve springs. He drops me off in the conference room and leaves to fetch his partner, Larry Luchi. And then I spot it on a dusty shelf: a heavy, slightly blackened coil mounted on a small piece of wood. A plaque underneath reads "Jeff Gordon, 1998 Rockingham Win." This tube of steel wire was the



This steel spring is 2.3 inches long and weighs 3.4 ounces. Its unglamorous job is to keep an engine valve closed. It does that so well it kicked off a secret Nascar horsepower war.



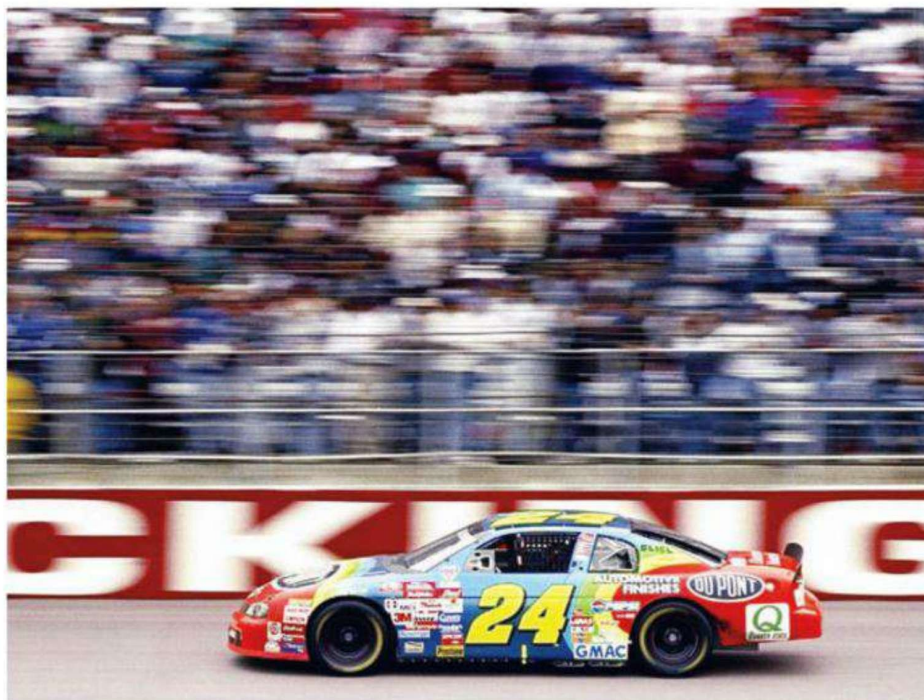
first PSI valve spring used in a Nascar race. It revolutionized engine building and the country's most popular motorsport, but few people have ever heard of it.

My interest in the subject began with a remark by legendary Nascar team owner Jack Roush. This was 15 years ago. I casually asked him if there was a single automotive part with the potential to dramatically alter racing stock cars. Roush isn't in the business of disclosing trade secrets, but he lit up. "Oh, yeah," he said enthusiastically. "Valve springs. We're getting higher quality valve springs that are going to let us do some tremendous things." It was an unexpected answer: These springs are humble engine parts. They simply keep the valves to the combustion chambers closed until the moment that a fresh dose of mixed fuel and air has to enter, or exhaust leave. Roush wouldn't elaborate—maybe he thought he had said too much already. Intrigued, I called other Nascar teams. But racers are as tight with their secrets as the NSA. I got a bunch of "no comment" answers and moved on.

Recently, Nascar's big rules change for 2012—a switch from carburetors to electronic fuel injection—made me wonder whether the innovations Roush hinted at had really changed the sport. I dug back into my contacts among Nascar team owners and engine builders. This time I was able to get people to talk. The highly publicized switch to fuel injection was a sideshow, they told me, in comparison with the changes in engine performance that occurred between 1998 and 2004. During those years, horsepower and engine revolutions had reached once-impossible heights. To understand how, I needed to ask Steve Bown about his valve springs.

Bown and Luchi return to the conference room, where I am contemplating the Jeff Gordon spring. "We were in the pits during the race," Luchi says. "Keeping our fingers crossed watching the 24 [Gordon's] car." It wasn't a particularly exciting race. Videos show Gordon hanging back for most of the contest but clearly dominating the final third of the race. At one point he has a 4-second lead. Gordon had just won the 1997 Nascar championship, and fans had no reason to suspect that anything other than driving skill was at work. But Nascar engineers knew. Inside his engine, 16 newly designed valve springs were ticking away, giving him an advantage. "By 2001," Bown says, "all the teams were using our springs."

RULES GOVERNING NASCAR engine architecture date back 50 years. They have evolved, but the basic regulations that limit engine size to 358 cubic inches and define the layout—two valves per cylinder and pushrod valvetrains—were written in 1968. For that reason, Mike Fisher, Nascar's managing director of research and development, has a strange job for someone with his title: keeping a lid on innovation. "We try to maintain a pretty tight box around what teams can do to the engine," he says. "We don't want one team having more power." If the

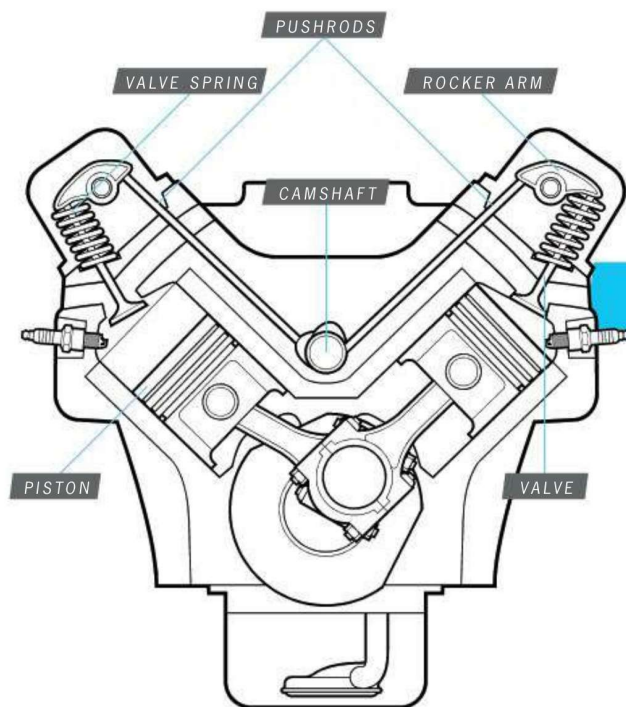


Jeff Gordon on his way to winning the 1998 GM Goodwrench Service Plus 400 at North Carolina's Rockingham Speedway. Few knew about the advanced valve springs inside his engine.

details can seem backward, like running carburetors and burning leaded fuel decades after passenger cars had moved on, there's a certain genius to the strategy. Nascar grandstands are packed partly because, in any given race, there are at least a dozen drivers who could win. In terms of lead changes and tight racing, a Formula 1 race is, by comparison, a procession.

Despite the straitjacket rules, however, Nascar drivers, engineers, and mechanics have always hunted for ways—some legal, others not so much—to get a performance edge. Counterintuitively, massaging the old tech of the Nascar V-8 at the granular level has produced highly advanced engineering. When it came to engine design, though, there was always one weak link. "The vast majority of engine failures—85 to 90 percent—are caused by broken valve springs," says Cecil Stevens, a longtime engine builder who now heads the engineering consulting firm Illusions Engine Development. The reason is simple: Valve springs have an incredibly tough job.

At each of the engine's eight cylinders, the intake valve lets in fresh air and fuel, and the exhaust valve releases spent gases—16 valves in total. A spring holds a valve closed until the valvetrain system pushes on the top of the spring, forcing the valve to open. Since an engine's output is directly related to the amount of air that flows in and out of the combustion chamber, the valves play a vital role. The larger the valves, and the farther they open, the



PUSHROD-ACTUATED VALVES MAY SEEM OUTDATED—THE LAYOUT IS AS OLD AS THE INTERNAL COMBUSTION ENGINE—BUT REFINEMENTS TO THE DESIGN HAVE NEVER STOPPED COMING. GM AND CHRYSLER STILL BUILD PUSHROD ENGINES.

greater the airflow and the horsepower the engine can produce—and the greater the stress on the spring.

As much as airflow dictates engine power, so does the speed at which the engine operates. Spin an engine faster and it will, in most cases, make more power. Randy Dorton, the chief engine builder at Hendrick Motorsports, Gordon's team, started a quest in the early '90s to increase engine rpm. Dorton died in a plane crash in 2004, but Jeff Andrews, who is now Hendrick's director of engine operations, has been at the team for about 20 years.

"Back then," Andrews says, "the biggest limiting factor [for higher engine rpm] was the valve springs." In 1998, a stock car's V-8 peaked at about 8000 rpm. The valves cycle at half the speed of the engine's crankshaft, so at 8000 rpm the valves open 4000 times per minute, or 67 times each second. During many oval races, engines remain at peak rpm for 500 miles—and the valve springs were operating outside their comfort zone.

The springs were a commodity product. Teams bought them from companies whose steady clients were mainstream car-makers. One such company is Peterson Spring, a privately held automotive supplier founded in Detroit in 1914. Dorton approached Peterson about building better valve springs. The company made some improvements, but it simply wasn't focused on racing. While there, Dorton met Peterson engineer

Steve Bown and ultimately convinced him that there was a need for a company that focused on racing valve springs. Bown enlisted Larry Luchi, a former Peterson CFO, to handle the business details while he focused on design and manufacturing. In 1996, with \$170,000 of startup capital, the two men formed Performance Springs Inc. (PSI). "During our first year, we had one customer," Luchi says. "Hendrick Motorsports."

TRACTOR-TIRE-SIZE spools of steel wire squat in the rear of PSI's minifactory. Bown guides me to a coiling machine that's about the size of a large refrigerator. Hydraulics draw the wire, and dies guide it into the spiral shape. When the spiral reaches a size dictated by computer controls, a cutter clips the wire and the newly born spring joins countless others in a bin. This first step in the process differs little from what you'd see in any spring factory. What comes next is the unique part: PSI's 41 employees take the springs through a nearly 50-step treatment process, coddling the parts like diamond-cutters tending gems. "We focus on quality, not cost," Bown says.

One of PSI's main goals now is to increase the fatigue resistance by reducing the number and size of microscopic flaws in the metal.

When steel wire is coiled into a spring, the metal becomes rough, like a board cut on a table saw, although the flaws are all but invisible to the naked eye. PSI heats its springs to more than 1000 degrees Fahrenheit in an oven that looks like a giant toaster, quenches them back to room temperature, shot-peens them in three steps—the process

is similar to sandblasting, but the medium is much finer—and polishes them. That's the quick version. It took Bown an hour to walk me through the process, and he declined to divulge many of the details. The finished product is actually two concentric springs, a design that increases spring rate—the force required to compress it a given distance—while ensuring that the piece can still fit in the allotted space. As a final step, workers in a darkened room inspect each spring under a microscope. If they find a blemish, it gets pitched. The rejection rate is about 25 percent.

Engine builders have their own way of testing springs: They use a Spintron, a machine invented in 1993 by Bob Fox to test the pushrods made by his company, Trend Performance. It's a simple device, basically an engine block with only a dummy crankshaft and the valvetrain components—camshaft, pushrods, rocker arms, valves, and springs. The engine doesn't run; it's cycled by a 60-hp electric motor connected to the crankshaft. With an array of sensors and high-speed video cameras, the Spintron reveals formerly invisible details, like how an undamped spring continues to oscillate after the valve closes.

In the win-at-all-cost culture of Nascar racing, where budgets hover at around \$20 million and winning the championship is a financial windfall, teams lined up to buy \$60,000 Spintrons, which validated parts and became invaluable research tools. And few balked at the extra expense of the PSI springs—\$28 apiece, or

40 percent more than previous springs. But while the springs themselves weren't pricey, they unlocked a technological arms race that did prove expensive.

Once valve springs were no longer the limiting factor on engine rpm, other weaknesses emerged. Doug Yates is the president of Roush Yates Racing Engines, a company that builds more than 500 Nascar engines a year. "Once you got a better valve spring," he says, "you could spin the engine faster. But for every extra 100 rpm, the next weakest link showed up." Piston assemblies were lightened to lower the forces caused by the higher speeds. The camshaft was positioned higher in the block to reduce the length and the weight of the pushrods. Special coatings and bearings reduced friction.

In 1998, the best Nascar V-8s revved to about 8200 rpm and produced roughly 700 hp. In the following six years, the maximum engine rpm climbed to 10,500 and the horsepower to 900. In the process, the Nascar engine builders broke through what were once thought to be ironclad boundaries. Take piston speed, for example. It was once believed that the upper limit for the piston speed of a Nascar V-8 was about 4500 feet per minute (fpm). F1 engines, which are considered to be the most sophisticated racing engines, have piston speeds of about 5200 fpm. But in 2004, the Nascar V-8 outdid even the F1 motors with piston speeds of 5400 fpm. "The F1 guys came over," Yates says, "and they couldn't believe what we'd done."

These changes weren't cheap. Say a team designs a new camshaft that opens the valve farther, to take advantage of the new springs. Testing the cam requires a new set of valve springs (\$500), the camshaft (\$3000), valves (\$3000), and assorted other costly items, all adding up to about \$10,000. To validate the test, it has to be repeated, so it's \$30,000 for just one new part. If something fails, the part gets redesigned and



Steve Bown (left) and Larry Luchi at their Michigan-based valve-spring factory. While the high-tech springs enabled Nascar V-8s to produce nearly 1000 hp, the business plan had modest origins: The pair formulated their strategy as they fixed up Luchi's lakeside cottage.

the tests repeated. Now multiply that process over the hundreds of parts in an engine. "It was a financial war to not only get an edge, but to simply keep up," Yates says. The result was to concentrate a significant horsepower advantage at the few shops that could afford to develop the high-revving engines. By the early 2000s, according to Andy Randolph, technical director at Earnhardt-Childress Racing Engines, the field was splitting between those teams that had engineered high-rpm engines and those that hadn't. "The races were turning into rpm battles," he says.

This rpm race ended in 2005, when Nascar, concerned about maintaining a level playing field and limiting top speed, introduced the gear rule. By mandating specific gear ratios for each track and applying a little math, race officials can compute the maximum engine rpm. "It's the mechanical way to control engine rpm," Nascar's Mike Fisher says. "We target about 9000 to 9200 rpm on a steady basis, with a peak of about 9500."

The effects of that tumultuous six-year period are in plain view every Sunday. Today, engines are relatively unstressed, which is why failures are now rare. And where once more than a dozen shops and teams produced engines, now there are just a handful. For the moment, the field has been equalized: Last year, there were 17 different winners, a 30 percent increase over 2008.

At PSI, they're still testing and tweaking. Before I leave, Bown shows me the latest prototype. I hold it up next to the Jeff Gordon spring. The new one is half as thick. "We're getting steel made specifically for us," Bown says, "and the springs can withstand even higher stress levels." That means the engine builders can open the valves a little more, inching up the power levels again. So far, no team is using the new spring, but it's only a matter of time. There are rumors that some teams have found a way to increase engine rpm past 9500, despite the gear rule. They continue to experiment with aerodynamics, suspensions, and tires. And lap times drop a bit each year. **PM**



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Annual deaths from intercity and charter bus crashes have tripled since the 1990s.

BY KALEE THOMPSON

**CURBSIDE MOTORCOACHES OFFER BUDGET
FARES, ALONG WITH OVERWORKED DRIVERS,
OUTDATED EQUIPMENT, AND LOUSY
SAFETY RECORDS. DEADLY
CRASHES ARE ON THE RISE.**

O

n a recent Thursday morning, Mike Lin pulled a cherry-red, 59-passenger bus up to the curb along Allen Street in lower Man-

hattan's Chinatown. A handful of people had gathered on the sidewalk, and as they climbed into the coach, Lin stepped down from the driver's seat to help a bearded young man load an oversize green backpack and a pair of wooden stilts into the luggage compartment. For the past four years Lin has worked full-time for a small bus company called Eastern Coach, usually driving a daily New York-to-D.C. round trip. He leaves the curb at 10 am and, if traffic is light, arrives in

Washington, D.C., by 3 pm. At 4, he pulls away from the curb again, hoping to deliver his passengers—who pay \$20 one way—to Chinatown before 9:30 pm. After that, he returns the bus to a Brooklyn parking lot and takes the subway home to Queens. If he's lucky, he's in the door by midnight.

Lin used to work for a more established company, but he didn't like the rules: "I had to wear a uniform. I couldn't talk to passengers while driving. I couldn't smoke around the bus," he says. His old company usually hired separate drivers for the trips to and from D.C., and the bus was equipped with a speed governor that prevented the driver from breaking the posted limit. "Everybody speeds a little," says Lin, who traveled at a steady 70 mph along a stretch of highway marked at 55 while many passengers dozed in the half-empty bus. What none of them knew was that Eastern has one of the worst safety records of any American bus company, ranking in the top 5 percent in unsafe-driving violations.

MORE THAN 750 MILLION PASSENGERS TRAVEL

by motorcoach each year—more than those who take Amtrak and domestic flights combined. The number is up recently, due in part to the weak economy—when money is tight, people take the bus. Nowadays, they have an abundance of options. Dozens of new carriers have joined established companies such as Greyhound and Peter Pan. Many of them, like Eastern, are curbside operators that keep overhead low by forgoing a terminal and picking up and dropping off passengers on a public street.

But there's a hidden cost to a cheap ride, as the nearly 30 fatalities from bus accidents in 2011 illustrate well. March was a particularly bad month, beginning with a grisly crash in the Bronx. A bus returning to New York City's Chinatown from the Mohegan Sun casino in Connecticut flipped on its side and skidded into a highway signpost, killing 15 people and injuring 18 more. Two days later, an accident on the New Jersey Turnpike killed one passenger and the driver. One week later, a chartered motorcoach rolled over on a New Hampshire highway, resulting in several serious injuries.

On May 31, there was another deadly crash on Interstate 95, just outside Doswell, Va. The motorcoach,

operated by a company called Sky Express, was in the right-hand lane just before 5 am, halfway through a 10-hour trip from North Carolina to New York City. As the highway curved gently to the left, the driver—who later admitted to falling asleep at the wheel—didn't alter course. The bus traversed a section of rumble strips before it crossed the shoulder entirely and kept going onto a grass embankment. It careened 381 feet before it rolled onto its roof and finally skidded to a rest another 80 feet from where it had left the highway.

The roof was crushed and the windows shattered. Like most motorcoaches, the 37-year-old bus had no passenger seatbelts. First responders were faced with chaos: From inside the bus came groans of pain and screams for help. Outside, broken glass, duffel bags, and suitcases littered the ground. All 58 passengers had to be transported to area hospitals, dozens with serious injuries. Four passengers died. The only person who didn't require professional medical care was the driver, 37-year-old Kin Yiu Cheung. He was also the only person on the bus whose seat was equipped with a seatbelt.

FOR MANY YEARS, INTERCITY BUS travel was extremely safe. In the 1980s and 1990s, there were about six to 10 motorcoach fatalities annually (a figure that includes intercity buses and chartered tour buses but excludes school buses and municipal city buses). Then a disturbing trend emerged. "We started to see the numbers creep up to around 25 to 30 fatalities a year, which worried us considerably," says Norm Littler, executive director of the Bus Industry Safety Council, a group of industry veterans that develops and promotes motorcoach safety procedures.

The increased risk corresponds to the rapid growth of bus carriers in the late 1990s, Littler says. "There was a lot of capital around. The bus manufacturers started doing what [automakers in] Detroit did: They would build buses when they didn't have sales, put them on the lots, and basically try to collar anybody into buying one." At the time, Littler was getting frequent calls from people who wanted to start bus companies. "I would go through the various regulatory requirements, and it became very obvious very quickly they didn't care about that," he says.

Then, on Mother's Day in 1999, a chartered bus destined for a Mississippi casino ran off the road and plowed through a chain-link fence and into an embankment. Twenty-two people were killed and another 22 injured. "The driver should never have been behind the wheel," Littler says. "He had severe medical problems. He had a long history of drug use. It was a relatively new company that grew very rapidly and simply

should not have been in operation."

The crash turned out to be a harbinger. Between 1999 and 2009, 251 people were killed in 67 motorcoach crashes, according to a study by the American Bus Association. More than half the deaths took place on carriers that had already been cited by federal inspectors for unsafe practices; many of those were newcomers to the industry.

THE DIVISION OF THE DEPARTMENT of Transportation charged with governing bus safety is known as the Federal Motor Carrier Safety Administration (FMCSA). In recent years, the FMCSA has had a hard time keeping up with the expanding and evolving industry. The Mother's Day crash prompted new standards that would require rigorous inspection of any new bus company within its first six months of operation. The federal law included medical requirements for drivers similar to what the Federal Aviation Administration mandates for pilots. Enforcement,

though, remains weak. The driver in the March 2011 Bronx crash was working under a false name. Cheung, the driver in the Virginia crash, could not speak English, even though federal law requires it. Bus drivers are supposed to keep a log of their duty hours, and many companies use electronic punch-in systems to prevent the fudging of paper

records. Sky Express relied on old-fashioned paper logbooks, and Cheung—who was charged with reckless driving and involuntary manslaughter—hadn't updated his for two days. His behavior was not unusual. And neither was his ability to get away with it before the deadly accident.

As it turned out, the FMCSA had cited Sky

Right now,
someone rejected
from a job
trucking hazardous
materials because
of something in
his background
check can go
out and get a
passenger-bus
license.

Express drivers for fatigue an astounding 48 times in the two years preceding the Virginia crash. The company had violations for unsafe driving, vehicle maintenance, and hours-of-service rules that dictate how long a driver can remain behind the wheel. The upstart carrier—which owned 31 buses and employed 53 drivers—had had four prior highway accidents and the single worst score of any American bus company in the Driver Fitness category. Still, the FMCSA hadn't taken Sky Express off the road.

Michele Beckjord, a survival factors expert at the National Transportation Safety Board (NTSB), says this isn't unusual. "We've got a lot of unsafe carriers that are getting a 'Satisfactory' rating, but they've got major violations either in maintenance or in driver performance and behavior." The problem, she says, is that in order to reach the Unsatisfactory level in the FMCSA's numerical evaluation system, a bus carrier has to have terrible scores in several different areas.



Rescue workers tow a motorcoach back onto the interstate after it crashed near Doswell, Va., on May 31, 2011. Four of the 58 passengers were killed and many more injured. This was the fifth highway accident for the bus company, Sky Express—yet it had a "Satisfactory" rating from the Federal Motor Carrier Safety Administration at the time of the crash. Sky Express's former office in NYC's Chinatown has since been taken over by another discount bus line.

HISTORY HAS SHOWN THAT IN MOST fatal crashes, driver performance is the biggest factor. "In the past, we looked at motorcoach drivers as being the *crème de la crème*, the kind of folks who make driving an art," says Stephen Evans, head of safety for Pacific Western, one of North America's biggest bus companies. "We thought there wasn't a need to be watching over them. That's not as true anymore."

Last year, the DOT adopted new rules stipulating that all applicants for commercial driver's licenses (CDLs) be required to get a learner's permit; previously, passing a state-specific written test was all that was required. The rules also require states to begin using a standardized CDL test and to ban the use of foreign-language interpreters, who in some cases are thought to perpetuate testing fraud. States have until 2014 to come into compliance. The law also needs to be revised to allow a driver's CDL to be revoked for drunk driving or other offenses committed in noncommercial vehicles, the DOT said.

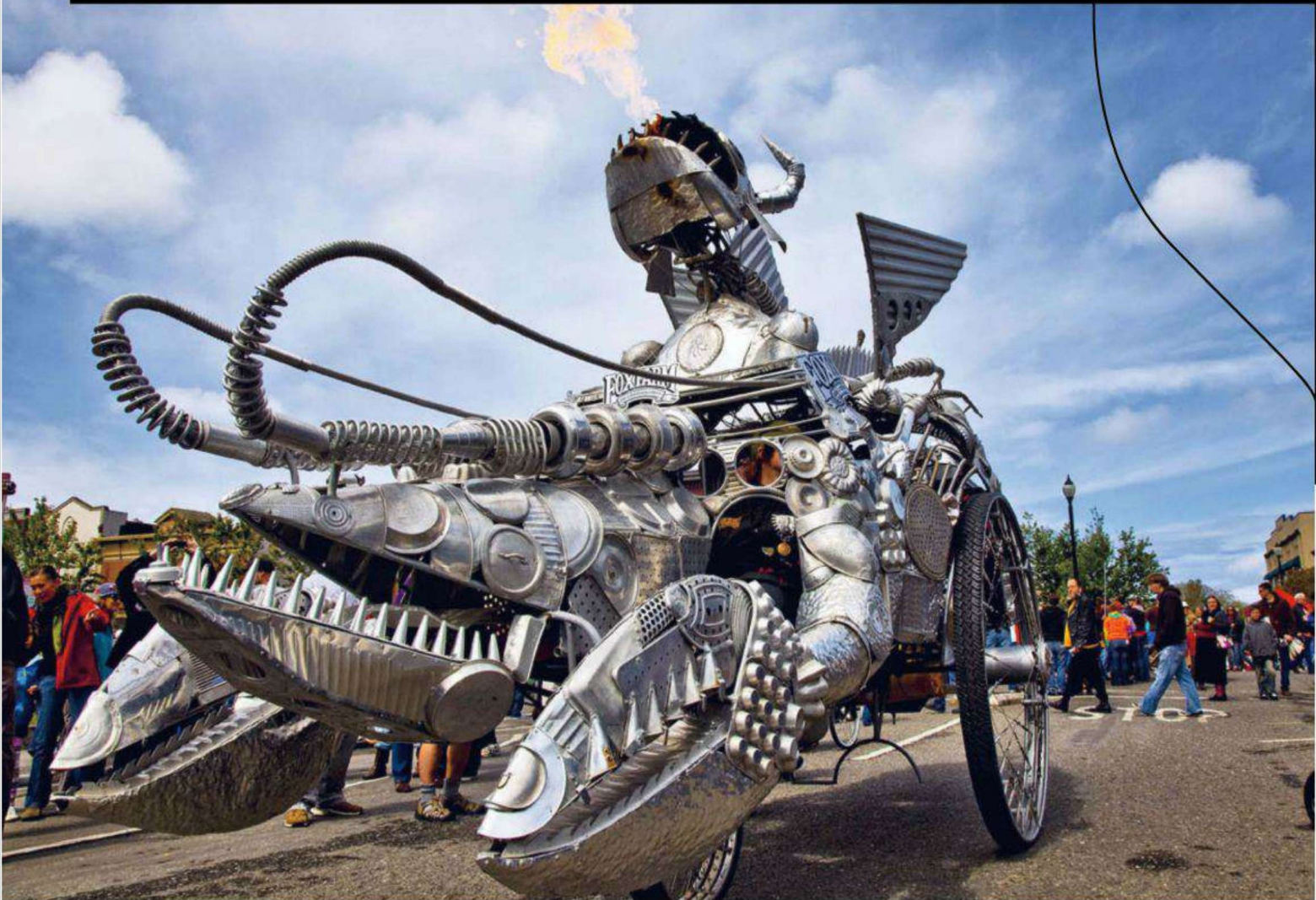
Right now, someone rejected from a job

trucking hazardous materials because of something in his background check can go out and get a passenger-bus license. Lack of law enforcement on the roads is another issue. Bus drivers know they're unlikely to be pulled over by police officers, who don't want to deal with a busload of annoyed passengers. As a result, they feel invulnerable and often get away with chronic reckless driving that, say, a professional truck driver never could.

FOLLOWING LAST SPRING'S SPATE OF DEADLY CRASHES, the FMCSA made efforts to step up its enforcement. In early May, the agency conducted 3000 unannounced safety inspections that led to 315 unsafe buses and 127 unfit drivers being taken off the road. Between January and October 2011, it shut down 37 unsafe bus companies and proposed an unsatisfactory rating for more than a dozen more. Those companies normally have 45 days to appeal the FMCSA's findings—unless they're found to pose an imminent hazard, like the Michigan company that was discovered to be transporting passengers in the cargo hold. (There were no seats for the six people inside the bus, the owner explained.) The company had been fined for the same

(CONTINUED ON PAGE 105)

What's 11 feet tall, breathes fire, and engages dozens of bicycle gears to cross land, sand, and sea? A vehicle built to conquer California's Kinetic Grand Championship. *by JAMES VLAHOS photographs by MARK PETERSON illustrations by SYLVIA PARK*



THE FAST & THE CURIOUS



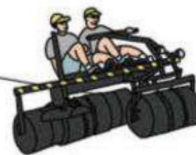
At the start of the three-day, 42-mile Kinetic Grand Championship race, Botton Feeders (left) breathes fire in the plaza of Arcata, Calif. Thirty-time participant Duane Flatmo created the metal beast using parts from previous years' vehicles. On day two, Visualize Whirled Peas (above) begins to traverse Humboldt Bay with the writer as a co-pilot.



12-FOOT-LONG PICNIC BASKET blocks the road ahead of us, a towering bottle of cabernet jutting from the top and ants the size of kindergartners scaling the wicker sides. As the basket sits in traffic, a herd of human giraffes—spotted tights, papier-mâché heads—sweeps by. Then from behind comes the sound of clanking metal. I turn around to confront a silver sea monster on wheels. Front-mounted lobster claws chomp hungrily, dragon jaws on the roof open wide, and a long tongue of flame scorches the sky.

Such are the sights of the Kinetic

Grand Championship, a three-day event on the northern California coast that is equal parts inventors' showcase, artistic performance, and serious race. It's the Daytona 500 meets Burning Man. Using no motors, the picnic basket, the sea monster, and three dozen other human-powered absurdities will travel 42 miles between the cities of Arcata, Eureka, and Ferndale. Though they look like carnival floats on acid, the contraptions must be designed to drive over pavement, dirt, and sand dunes, and even to navigate moving waters. "Kinetics is about art, speed, and engineering,"



says Monica Topping, former president of the organization that puts on the race. "It's the triathlon of the art world."

There are nearly a dozen kinetic races around the United States, from Port Townsend, Wash., to Baltimore, and all were inspired by the Humboldt County event. It was launched in 1969 by local artists Hobart Brown and Jack Mays and first won by a turtle that belched smoke and laid eggs. The event begins at Arcata's main square, where thousands of spectators snap pictures and a marching band plays hits from the 1980s. A slice of cake creeps past a pod of dolphins. A gangster's getaway car moves beside the space shuttle *Endeavour*. The Heroes of Gloryopolis rolls slowly along with a team of Marvel Comics-esque superheroes patrolling a metropolitan skyline. Ten pilots below pedal bikes welded to the remains of a Ford Ranger chas-

sis. The machine was engineered by resident Carl Mueller, who, like many kinetic racers, has an almost compulsive desire to tinker with everything from Legos to vintage steam locomotives. "I was born with a wrench in one hand and a gear in the other," he says.

And then there's the kinetic sculpture that I'm helping to race. I hunker down in a putrid-green, three-wheeled dune buggy called Visualize Whirled Peas, or VWP for short. Decorated with dangling tennis balls and spinning pinwheels, it has one tire up front and two in the back, and there's a similar configuration of seats for the trio of pilots. To my right is VWP's inventor, Mike Ransom, who built the contraption from donated dirt-track tires, abandoned bikes, and other dumpster-diving finds. Whether they are anticar environmentalists or monster-truck fans, most racers, like Ransom, relish



the challenge of turning trash into rolling treasure.

"How many bikes died to make that float?" a man on the street asks.

"Probably about six or seven," Ransom says. Each VWP pilot has pedals underfoot and controls a set of either 18 or 21 bicycle gears, which in turn feed into six more gearing ranges. Ransom, a computer programmer at the University of California, Davis, boasts that VWP has 244,944 possible gearing combinations. "Rube Goldberg would be proud!" the man replies.

A Kinetic Kop, wearing the buttoned coat and tall hat of a 19th-



Racers push Attack of the Funguys—which won the Most Improved and Best Pit Crew awards—up dunes on Samoa beach (far left). The pilots of The Jeep and The Heroes of Gloryopolis share a laugh at the start of the race (left). Woody Endeavour takes on Dead Man's Drop (above). Of the ACE teams—that completed the entire race without using relief pilots or breaking other special rules—Woody Endeavour finished second place for time.

century British police officer, approaches VWP. He checks that we have the toothbrushes, the horn, the 2-gallon pail, and other items mandated by the gleefully arcane rules of the contest. The inspection ends, and at noon, a siren cuts through the air. Pedaling furiously and jockeying for position, Team VWP makes three laps around the square, then heads west out of town. The race is on.



KAY, BE A BUZZKILL. ASK WHY. Why would people spend hundreds of hours to create all-terrain racing sculptures? The obvious answer is because kinetic

racing is fun, but the rationale goes deeper than that. Events like the Kinetic Grand Championship attract both studio artists and grease-stained engineers with the same intoxicating lure: an oddball challenge whose arbitrary constraints inspire wonderfully unconventional solutions. The mandate that all entries be human-powered makes the race more accessible to students and hobbyists. And the no-engines rule gives the race a third component besides artistic design and mechanical engineering—human sweat. “I’ve always loved the physical, athletic part of

the race,” says racer Duane Flatmo, a 30-time participant.

This year Flatmo rides in Bottom Feeders, the fire-breathing sea monster he created. An artist who is as comfortable with paint on canvas as he is with taking a blowtorch to steel, Flatmo has competed on the TV show *Junkyard Wars* and performed a musical number—playing a flamenco guitar with an electric eggbeater to strum the strings—on *America’s Got Talent*. He built Bottom Feeders with a dazzling array of recycled materials, from cupcake tins and colanders to irrigation equipment and pieces of airplane wings. “I try to create a piece of eye candy, something that people just can’t help but get out their camera and take a picture of,” Flatmo says.

Bottom Feeders falls behind VWP as we pedal out of town into an agrarian landscape. Cows cluster against fences that line the two-lane road and stare at the sculptures passing



CRAZY RACES

ACROSS THE U.S., BOLD TINKERERS ARE TURNING ORDINARY OBJECTS INTO WHOLLY ORIGINAL HOME-BUILT VEHICLES. FROM BAR STOOLS TO POWER TOOLS, HERE ARE THE WEIRD AND WACKY WAYS DIYERS ARE SATISFYING THEIR NEED FOR SPEED.

by Katie Hendrick

BAR-STOOL RACES

Drummond, Wis.

Many have barked brazen words from atop a bar stool. But only the truly intrepid add skis and take the souped-up seat for a ride down a snowy slope. The stools must be at least 27 inches tall, and contestants have to stay seated for the one-fifth-of-a-mile sprint. The sitting rule began in 2000 primarily for rider protection, though staying seated also lowers the center of gravity, which increases stability and speed.



COLLEGIATE CONCRETE CANOE RACES

Regionals nationwide

To create the concrete boats for the championship "America's Cup of Civil Engineering," competitors use concrete made of expanded glass spheres, multiple cementitious materials, and specialized admixtures. Teams spend upward of 4600 hours researching, constructing, and training. "You're out there on the lake with 20 other teams, and everyone's waiting to see which canoes turn into submarines and which will take it away, usually determined by



tenths of a second," says Cal Poly alumnus Kyle Marshall, who competed for four years.

POWER-TOOL DRAG RACES

Mora, Minn.

"Until you've tasted the thrill of victory and smelled ionized electricity and burning rubber, electrical insulation, and, sometimes, flesh, you really haven't lived," says Jon Larson of Mora, Minn.'s annual power-tool race. Racers



Adventurous souls leave their beers on the bar and strap skis to stools in Drummond, Wis.'s annual race (above left). DIYers across the country can embrace their inner mechanic by building retro-classy cyclekarts (above right). The duct-taped boats in Key West's annual Minimal Regatta are as likely to sink as make it to the finish line (left).

turn electric concrete saws, angle grinders, and other tools into makeshift motors that power skateboards, scooters, bikes, and go-karts. All entrants must use recognizable 110-volt tools (up to 20 amps) that can be reused post-race.

CYCLEKARTING

Nationwide

This group began as a handful of self-professed "disenfranchised, alienated, and

enlightened eccentrics" with a love for DIY projects and disdain for the status seeking of the automobile world. Often inspired by actual cars—including Bentleys, Millers, and Bugattis—cyclekarts are nimble, elegant machines that can travel up to 40 mph. And none are as expensive as they look. In fact, Michael Stevenson of the Association of MotoCycleKartists says that the group has dismissed members

who created more ostentatious designs. "They just didn't get what it's all about."

MINIMAL REGATTA

Key West, Fla.

Key West's homebuilt-boat race allows only a few materials—a sheet of plywood, a pound of fasteners, a roll of duct tape, two 2 x 4s—to create vessels that resemble everything from surfboards to Spanish galleons. Steve King, a 20-year veteran, enters for the gratification of "building something no one expects to float and knowing that sinking's almost as fun as winning."

THE GREAT WEST END & RAILROAD SQUARE HANDCAR REGATTA

Santa Rosa, Calif.

"For the delight and edification of all who attend," this race challenges participants to relive the era when the railroad was king, while applying today's style and gear. The only regulation: no motors, batteries, or rubber bands. "Entries have to be human-powered," says event co-creator Ty Jones, "which means a lot are based on bicycles that are cut up and reloaded back in different configurations." Aside from the common presence of spokes, aesthetics vary widely. Jones has seen designs resembling traditional pump cars, mouse wheels, and even the ship from *Willy Wonka & the Chocolate Factory*.



Before they become Grand Champions, ACE medalists, and Pageantry winners, the Tempus Fugitives—headed up by James Smith—enjoy a smooth section of road on their way to victory. It is Smith's third time racing in this machine.

by. Cruising atop oversize tires, VWP passes a rickety white taco truck. Papier-mâché skeletons, one dressed as a bride and the other as a groom, sit in the front seats and grin toothily. NEWLYDEADS, reads the sign over their heads.

A couple of hours later, after driving down a long stretch of beach with waves sliding up beneath the tires, we turn inland and face a steep set of dunes. VWP makes it up the first one but stalls midway up the second. No matter how much we strain against the pedals, the machine won't move

forward. The front wheel starts lifting up off the steep slope, and the whole contraption tilts dangerously backward. "Okay, that's it!" Ransom calls, signaling for everyone to jump off. "We're pushing." After we reboard at the top of the hill, which is called Dead Man's Drop, a judge asks if we want to scout the steep descent on foot. "Nope, we'll be fine," Ransom replies as we wheel over the sandy lip. And he's right.



THE NEXT DAY OPENS WITH A 1-mile sojourn through Humboldt Bay. The Jeep, a black, 1½-ton monster truck with four-

wheel drive and four-wheel steering, loses a pontoon 50 yards in and begins to capsize, causing at least one co-pilot to jump overboard, screaming. The Jeep was overbuilt by design, says its maker, Chris Gardner. "I looked at all the other sculptures and they're awesome pieces of engineering, light, and little, but they're not rock crawlers," the 21-year-old says. "I wanted to build a tank."

I'm not comforted by his accident, nor by the conversation I had the day before with Dave Richards, a

(CONTINUED ON PAGE 104)

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DIY

Tech

Personal Prototyping

IF IT'S GOOD ENOUGH FOR BOEING, IT'S GOOD ENOUGH FOR YOU: 3D MODELING (AND PRINTING) HAS COME OF AGE. BY JOHN HERRMAN

➔ **There was nothing** wrong with Stijn van der Linden's screwdriver set, save for one thing: Years of use had worn away identifying marks from the handles. Tired of fumbling through a pile of tools every time he needed a No. 2 Phillips, van der Linden sat down at his computer. Using a PC program called 3ds Max, he created a complete 3D model of a labeled, ordered case,

INSIDE

FIXING SCREEN SCRATCHES + CELLPHONE SURVIVALISM + SUPER-RESOLUTIONS

custom-fitted for his old tools.

When he was finished, he sent the file to his desktop prototyper, or 3D printer. About an hour later his tool case materialized in white ABS plastic. Everything fit perfectly.

Van der Linden, an electrical engineer by training, is admittedly not a beginner: 3ds Max is a professional 3D tool used to create, among other things, computer graphics for Hollywood films such as *Iron Man* and *Avatar*, and his 3D printer, the pp3dp Up, retails for more than \$2500.

Nonetheless, he says, the appeal of DIY 3D modeling and printing is universal. "You're losing a lot of the limitations in the physical world," he says. "For my whole life, I always wanted to make stuff. Now I can make anything I want." It's true: An influx of easy-to-use software and on-demand printing services has made it possible for DIY-minded individuals—not just professional engineers—to render their designs, be they brand-new inventions or just hard-to-find replacement parts, in 3D and have them printed in plastic, glass, or even metal. Here's how to get started.

3D for the Masses

➔ **When most people** think of 3D modeling, they think of CAD (short for computer-aided design). CAD conjures images of engineers toiling over green-on-black wireframes. This perception isn't entirely unfounded; 3D CAD modeling of the advanced, inscrutable sort has changed what it means to be an engineer and revolutionized everything from toy design to aviation. It has also been, until recently, almost completely inaccessible to civilians.

Today, though, 3D modeling has quietly opened to the mainstream. Free or affordable tools have emerged that are designed with ordinary people in mind.

More importantly, these tools have found real, practical roles. Some, like traditional CAD programs, help people—tinkerers, inventors, artists—visualize objects in three dimensions. Others simply help you plan a new room in your home or reconfigure an old one.

Getting Started

➔ **The biggest hurdle for would-be 3D-modelers** isn't the price or the complexity of the software—it's the overabundance of options. There are pro-level modeling and rendering suites, finicky engineering tools, and simplified-to-the-point-of-uselessness art apps. In search of an entry point, I found an app called Tinkercad.

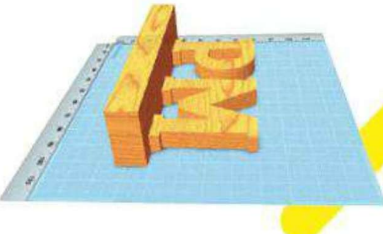
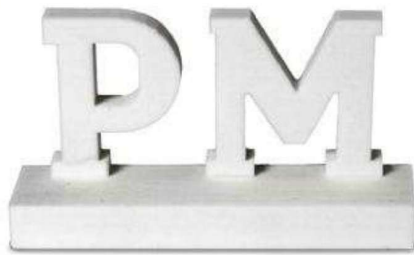
This free application runs inside a Web browser on nearly any PC or Mac and contains just the right level of functionality—it's capable enough for real 3D modeling, but not so complex as to put you off. It's a solid-modeling program—much like most professional CAD apps—which means that its models are an agglomeration of points in space rather than a hollow group of stitched-together polygons. With its emphasis on solid, volumetric materials, this type of modeling is particularly well-suited for 3D printing, and Tinkercad has a button that creates a 3D-printer-ready file instantly.

To get started, navigate to tinkercad.com and create a free user account. I was presented with a blank slate—or, in the parlance of 3D modeling, an open work plane. Building in Tinkercad is conceptually simple: In the Add mode, you select a shape—a box, a pyramid, a cone, or a cylinder—along with a size. You then stamp this shape into 3D space; clicking and dragging will stretch the shape as far as you want. The Sub (for "subtract") mode lets you use the same shapes for object removal. One of the easiest practical projects is a shirt button: With the Add tool, stamp a disc that's 16 mm wide and 2 mm thick. With the Sub tool set at 3 mm wide and 2 mm thick, stamp out two buttonholes near the center of the disc. That's it.

My first nonbutton project was admittedly a modest one: a *POPULAR MECHANICS* paperweight. It was to be about 4 inches wide, with a thick, 1-inch-deep base. Our trademark PM lettering would be perched on top. (Swap for your initials if you want to follow along.)

Modeling a shirt button takes about 2 minutes; my paperweight took a great deal longer—about an hour, including 15 minutes to get used to the app and no small amount of trial and error. Getting used to the stamp-and-cut behavior of the program was the biggest challenge; in its current incarnation, there's no way to move or resize an object—a block, for example—after it's been placed on the grid. Getting the spacing of the letters right took a few tries.

The core of the paperweight was composed of just seven shapes: one block for the base, four blocks for the M, and one block and a disc for the P. After creating the core, it

	VERSUS BITS AND ATOMS
	A sandstone rendering of the model, printed by Shapeways. OBJECT MASS: 2.3 ounces 
A 3D model of the <i>POPULAR MECHANICS</i> paperweight, created in the online modeling app Tinkercad. FILE SIZE: 348 kilobytes	

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DIY

Tech 3D PRINTING

was a matter of cutting, trimming, and adding accents. I subtracted small pieces of material from the middle of the M to match our iconic typography and carved out a hole for the P. I used small cubes to stamp serifs onto the letters and did cleanup with a 1 x 1-mm subtract tool. The end result was good enough. The next step was to make the paperweight real.

3D Printing

POPULAR MECHANICS has devoted a fair number of pages in the past few years to a company called MakerBot, whose 3D printers can create small, plastic prototypes in just a few minutes—all they need is a healthy supply of ABS plastic and a 3D-model template from a program like Tinkercad. MakerBot's machines are affordable, but only relatively: At \$1000, they're far cheaper than industrial prototyping machines, but out of reach for most hobbyists—including me. Plus, I was making a paperweight, and MakerBots print only in plastic. I wanted something with heft—glass or stone or even metal. That's where Shapeways, an on-demand 3D printing service, came in.

Sending my model to Shapeways was a two-step process: From Tinkercad I exported my project as an STL file, the industry standard for 3D printing; at shapeways.com I just clicked the Upload button on the front page. Ten minutes later, I got a message saying that my model had been approved, and I was presented with nearly 20 choices of materials. For \$25, I could have the project printed in ceramic. For \$930, I could have it cast in sterling silver. I made my selection (sandstone, \$36) and I would have my paperweight within two weeks. I've already chosen a followup project: Ever the picky tech editor, I'm custom-designing a case for my smartphone.

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Half CAD tool, half video game, Autodesk Homestyler (homestyler.com) lets you visualize home-improvement plans in 3D. Virtual rooms can be furnished with products from companies including Kohler, KitchenAid, and DuPont. You can then explore the finished room in real-time 3D, or export it as a photorealistic rendering.



Advanced Prototyping

➔ **Software for 3D modeling ranges in price** from free to thousands of dollars and varies hugely in complexity. Tinkercad is a fantastic starting point, but you'll hear a lot of other names when you dive into the world of 3D modeling.

SketchUp, by Google, is a popular program by virtue of its tie-in with the company's 3D-mapping program, Google Earth. (Google encourages users to populate its virtual maps with 3D replicas of real buildings.) Blender, another free program, is an open-source alternative to professional programs such as 3ds Max. It's versatile—there's really nothing you can't do in Blender—but it has a steep learning curve.

The app 123D, new from Autodesk, the company that makes the industry-standard professional CAD software, is a well-balanced tool kit for intermediate 3D-modelers and connects natively with Shapeways for easy 3D printing. Once you're comfortable in a program like Tinkercad, you can find your way in 123D.

There's room to grow with Shapeways as well. Once you're satisfied with your design, you can list it for sale on the site. You choose the material options and markup, and they handle the ordering, printing, and shipping. "Three-D modeling started as a hobby," says van der Linden, but after launching a product line that includes kinetic toys, geometric sculpture, jewelry, and desk lamps (Shapeways can print objects up to about 27 x 15 x 22 inches), it's quickly becoming a healthy source of income.

Roman Vasyliov, a freelance designer, had been building model cars and airplanes for years before discovering 3D printing. His obsessively detailed World War I-era aircraft models now net a steady stream of income. (The top seller is a 1:44-scale model of the Caudron G.4, a French biplane bomber.) "I was really surprised that 3D modeling has become another branch of my hobby," he says, "and now, my work."

Modeling and printing in 3D has everyday applications, too. In an hour or two, Tinkercad or 123D can help you replace that once-irreplaceable knob on your priceless old guitar amp, for example. Last year a man named Duann Scott asked the manufacturer of his high-end baby stroller, Bugaboo, for a part to repair a broken hub lock. When the company said it would charge \$250, he scoffed. Scott took apart the hub, figured out what he needed, modeled the parts on his own, and had them printed in stainless steel. Total cost: \$15.

PM

TOUGHEST ON THE BLOCK



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Digital Clinic

by John Herrman

Q

My tablet slid off my lap and onto a concrete floor. Everything still works, but now the screen's got a bunch of scratches. Is there any way to fix this?

Screen-Scratch Surgery

A I wasn't able to find a commercial product that claims to fix scratches on a glass touchscreen, but a Google search turned up a variety of improvised remedies. These run the gamut from fishy to believable, but have one thing in common: a near-total lack of substantiation. I decided to sacrifice a disused iPhone 3G for testing, a process that started with a pair of keys and ended, painfully, with a screwdriver.

One standout claim is that a coat of Turtle Wax will minimize scratches; in my testing, it did nothing of the sort, and left behind a thin film of wax, which attracted fingerprints. Others point to 3M scratch remover for cars as a possibility; three rigorous applications did nothing for the iPhone. Displex, a polish for plastic screens and another favorite among online DIYers, left the screen immaculately shiny and seemed to darken the appearance of scratches, but this was a temporary effect of lingering residue. I even scrubbed the screen

PHOTOGRAPH BY PHILIP FRIEDMAN

with toothpaste until my arm was sore, which had no lasting effect.

There is, of course, an extreme option: glass buffing. With a small drill attachment and a tub of cerium oxide compound (and for deep scratches, some sandpaper), it is possible to grind scratches out of a screen, the same way you would buff scratches out of auto glass. My testing indicates that this is a very bad idea. Glass grinding requires the steady application of wet-mixed cerium oxide, which is quite messy, and sprayed water, a natural enemy of all things electronic. I attempted to seal the phone with tape, but the sticky cerium slop found its way into almost every opening, drying like a fine cement.

As for the scratches, I was just starting to see improvement when I noticed a new type of blemish. My inconsistent water application had resulted in overheating, which destroyed an area of the underlying LCD. For a touchscreen device, glass grinding is, in other words, overkill, with an emphasis on "kill."

The best solution, short of screen replacement, is a screen-protector film. It won't just shield from future scratches—it will make some shallow ones invisible.

Give Me a Signal → If I'm lost in the woods, should I climb to the top of a hill to get cell reception?

Satellites play no role in cellphone reception, so getting closer to the sky, or getting a clear shot at it, won't necessarily result in a connection. Cellular reception largely depends on how close you are to a cell tower, what geographical and man-made obstructions stand in between, and how many people are using the tower at a particular time (more users decreases a tower's range).

That said, elevation can help. "It's hard to say that this is a hard and fast rule of thumb," says Brian Josef, assistant vice president of regulatory affairs at the CTIA—The Wireless Association, but climbing to get reception is "common sense." A higher elevation could put you in line of sight with a cell tower, which may help you get that one crucial bar of coverage.

This common sense applies only if coverage is a possibility; a truly remote location is not likely to have any service at all. Ken Phillips, chief of emergency services at Grand Canyon National Park, warns that the blind pursuit of cellphone connectivity could be counterproductive. "In the vast majority of the canyon, there's no cell coverage," he says. By climbing to the top of a rock formation or butte, especially during severe weather, "you're just exposing yourself to risk." If you're genuinely lost, focus on your situation, not your tech: Gather water, build shelter, and stay put.

Super Hi-Res → My phone has a 4.65-inch display with 720p resolution. My TV is 720p too, but it's a 40-incher. Why don't TVs have much higher resolutions?

Here's a quick back-of-the-napkin calculation: If a 40-inch TV were as pixel-dense as a 720p smartphone, it would have a resolution of about 6200 x 11,000 pixels—6200p. Manufacturers are beginning to tease TVs with 4K displays (that's 3840 x 2160 pixels), but Raymond Soneira, president of DisplayMate Technologies, says that there isn't much to gain from a resolution race. For direct-view HDTVs, in American homes, it's absolutely pointless to increase the resolution [beyond HD]," he says. "A phone is held at 10 or 12 inches, and a TV is typically viewed at least 6 feet away. At those distances the resolution, to your eye, is the same." And then there's the issue of price: The first 4K TVs will cost about \$10,000. **PM**

Got a technology problem?

Ask John about it. Send your questions to pmdigitalclinic@hearst.com.

While we cannot answer questions individually, problems of general interest will be discussed in the column.



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DIY

Home

A Place in the Sun

A STURDY BENCH WITH A CLASSIC LOOK PROVIDES A GREAT ACCENT IN ANY YARD. *BY JOSEPH TRUINI*

➔ Few things refresh the human spirit so thoroughly as simply sitting outside on a beautiful day. It's even more satisfying if you sit with somebody, and if the seat is something you've built, well, so much the better. We'd like to help by suggesting your next project—this garden bench. Start with seven pieces of lumber and a handful of hardware. Spend a couple of free afternoons cutting and boring. When you're done, you'll have fine seating for one or two—in fact, three kids could even rest comfortably on it. It's built to last, with a slatted top made from 2 x 4 lumber turned on edge, bolted to stout 4 x 4 legs. We recommend using Western red cedar, which is naturally rot resistant. Build a bench now, and you'll be ready for that first warm day this year and for years to come.

INSIDE



BORE BIG HOLES + BUILD A WIND CHIME + RECYCLE KITCHEN CABINETS

PHOTOGRAPH BY LAJOS GEENEN

DIY

Home CLASSIC GARDEN BENCH

Cutting and Drilling

MAKE THE SHOULDER CUTS

→ With a power miter saw or a circular saw and a crosscut guide, cut four legs, nine seat boards, and 12 spacers to length. Cut the tenon into the top of each leg with a table saw. Make a shoulder cut into opposite sides of each leg. Clamp a small stop block to the rip fence, and adjust it so the outside of the blade is $3\frac{1}{2}$ inches from the stop block.

With the blade set to $1\frac{3}{8}$ inches high, butt the leg against the stop block, and use the miter gauge to push it across the blade [1].

PARE TO PERFECTION

→ Flip the leg over and make the second shoulder cut. Repeat for the other three legs. Move the fence to the side and, while holding the leg against the miter gauge, make repeated passes over the blade to remove the bulk of each tenon. **Pare away slivers of wood with a razor-sharp chisel [2].**

ADD THE SPACER BLOCKS

→ Blocks $\frac{3}{4}$ inches thick and $3\frac{1}{2}$ inches square must be nailed to six 2 x 4 seat boards as spacers. **Using polyurethane glue and 1½-inch 4d galvanized finishing nails, fasten a block with the outer edge $3\frac{1}{2}$ inches from each end [3].**

ATTACH THE LEGS

→ Use the glue and 1½-inch galvanized decking screws to fasten a leg at each end of two seat boards that don't have spacers attached [4]. Mark center points on the two outer seat boards for the counterbored holes for the nuts and rods that hold the seat together. On these points, drill a $\frac{3}{4}$ -inch-deep

hole with a 1-inch-diameter spade bit. The counterbored holes will receive a wood plug to hide the hex nuts on the ends of the threaded rods.

BORE THE ROD HOLES

→ To drill the $\frac{7}{16}$ -inch-diameter holes for the rods,

make a plywood jig and bolt it onto a drill guide. This ensures that the hole through each piece is accurately positioned relative to the board's end.

Hold the jig against the end of each seat board, then drill through the board and spacer block [5].

Bench Assembly

CLAMP THE PARTS

→ Glue and clamp the parts together on a workbench [6]. Hacksaw each threaded rod to a length of 19 inches. Thread a nut onto the end of



DIY

Home CLASSIC GARDEN BENCH

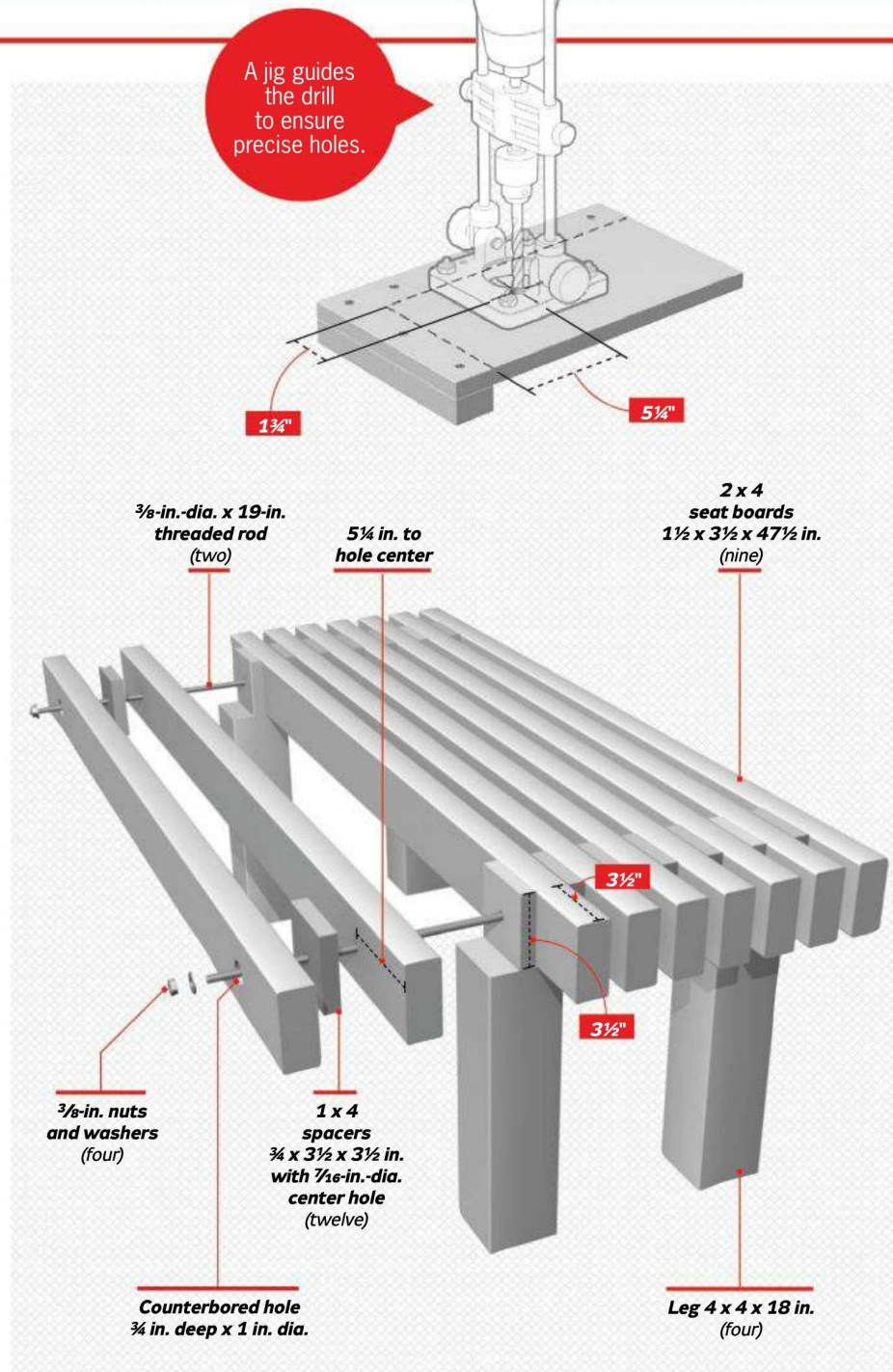


each rod, then remove the nut, to clean up saw damage. Feed each rod through its hole; use light hammer strikes, if necessary.

FINISHING TOUCHES

→ Place a washer and nut on the ends of each rod, and ratchet tight with a $\frac{9}{16}$ -inch socket [7]. Glue a dowel plug into each hole and cut it flush to the face of the seat board [8, 9].

Smooth surfaces with belt and orbital sanders, using 80- and 100-grit sandpaper, respectively. Use a clean brush to remove sanding dust, and apply a clear wood preservative. This should provide sufficient protection for the wood, but to preserve the finish, keep fallen leaves brushed off (tannins will stain it), and store the bench indoors in winter. **PM**



Shopping List

2 x 4 x 8 ft (5 pieces)
1 x 4 x 4 ft (1 piece)
4 x 4 x 8 ft (1 piece)
 $\frac{3}{8}$ -in.-dia. x 36-in. threaded rod (2)

$\frac{3}{8}$ -in. hex nuts and washers (4 of each). Note: Outside diameter is $\frac{9}{16}$ in.
1-in.-dia. wooden dowel (1)

$1\frac{5}{8}$ -in. decking screws (1 box)
Polyurethane glue
 $1\frac{1}{2}$ -in. (4d) galvanized finishing nails (1 box)

Homeowners Clinic

by Roy Berendsohn

Take it easy when boring big holes. Regardless of the bit you use, back off to clear chips and sawdust, then proceed. It'll be easier on you, the drill, and the bit.



Q

Bore, Baby, Bore!

I've got some basement remodeling to do that entails drilling large holes in studs and joists. What works better, a holesaw or one of those big drill bits that plumbers use? I have a ½-inch drill. Will that do the trick, or should I rent a larger one?

A When plumbers and electricians need to drill a large hole in framing lumber or other material—to make way for pipes and wiring—they usually opt for a self-feed bit (above). Such bits max out at a diameter of about 4 inches. Another choice for the pros is the auger bit, which can drill holes about half that size. Holesaws present a third option, though they can be problematic, which I address below.

The last part of your question tells me that you understand an important, basic fact about using these bits: It takes a big drill with lots of torque to spin them. Plumbers and electricians use specialized tools with the chuck at a right angle to the motor. The 90-degree design allows what is known as a joist drill, or a stud-and-joist drill, to fit between wall studs and floor joists while driving the stubby self-feed bit. A popular version of the tool is the Milwaukee Hole Hawg (great name, eh?), an 11½-pound machine with a long piece of pipe for a handle. More advanced versions

of these drills have a clutch that prevents them from breaking your arm if the bit grinds to a halt and the torque transfers to the handle. Note: The Hole Hawg does not have a clutch; if you're concerned about this, opt for Milwaukee's Super Hawg, which has a clutch in the low-speed setting.

So, can a standard ½-inch drill power a self-feed bit? Maybe. Your drill will certainly get a workout—and you may risk frying the motor—if you use a bit larger than 2 inches. Any bit bigger than that probably dictates that you rent a more powerful drill; ditto if you're going to be cutting a lot of holes. Even so, this type of drilling is tough work. Take your time, and be sure to use a 12-gauge heavy-duty extension cord.

That brings us to holesaws. Certainly one of these bits can bore through framing lumber, especially when chucked into a ½-inch drill. But holesaws have some drawbacks. Their shape and cutting action don't eject chips and sawdust, so you

have to repeatedly back out the saw to clear debris. That makes a holesaw slower in thick material than a self-feed bit. You also need to pry out the plug of wood that the saw creates. Better-quality holesaws have stepped slots in their body to make removing the plug easier.

Be sure to gauge the size and position of any hole you drill so that it doesn't damage the framing lumber. The International Residential Code



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Hex-shank
self-feed bit

Bimetal
holesaw

For thick materials, consider the self-feed bit.

The self-feed bit is the go-to accessory for plumbers and electricians. Its large center screw pulls the bit into thick wood, hence its name. Its big teeth and cutting lip carve out the wood, sending chips flying in all directions.

The holesaw is better suited to cutting holes in thinner materials.

This accessory saws out a plug-shaped waste piece. While it works well in thick construction lumber, it's far more effective in thin materials such as drywall and plywood. Bimetal types can even cut sheet metal.



TORQUE MASTERS YOU CAN RENT OR BUY

The DeWalt DWD220 (1) has an E clutch that shuts down the tool to keep it from locking up and transferring the torque to you. It's rated for self-feed bits up to 2⁹/₁₆ inches. Milwaukee's 1675-6 Hole Hawg (2) is legendary for power and durability. It's rated for self-feed bits up to 4⁵/₈ inches. Makita's DA4000LR (3) is really a 1/2-inch drill with a removable head that can rotate 360 degrees for increased hole-boring access. It's rated for self-feed bits up to 4⁵/₈ inches.

PHOTOGRAPHS BY NICK FERRARI

allows a hole that's up to 40 percent of the width of a stud in load-bearing walls or 60 percent in nonbearing walls. (That translates to holes of 1¾ inches or 2¼ inches.) In either case, the hole should not be closer than ⅝ inch to the lumber's edge.

Those are the basics. For a more detailed take on the topic, have a look at the Western Wood Products Association's notching and boring guide online.

Caulk Talk ➔ I'm installing baseboard, door, and window-trim molding. I'd like your opinion: Should I caulk the trim to the wall?

In most cases, it's not necessary to caulk trim, especially if you carefully nail it to the studs so that the trim pulls tightly against the wall. But if you need to fill some gaps, use caulk sparingly. Cut the tube tip to a small opening and be fastidious about wiping off excess material.

To be clear, I don't have a problem with caulk; in fact, I use it all the time. But generally speaking, it's overused. Sloppy application is common, and not pretty. When the caulk begins to pull away from the trim and the wall, things can get ugly. If you use high-quality trim and do a good installation job, you can avoid the need to caulk altogether.

Through the Roof ➔ I'm in the military and have moved around a lot. Over the years I've lived in seven or eight houses, and I'm now considering buying a place in New Mexico. There's one house in particular I really like, but I'm concerned that its dryer vent goes up through the roof. Every house I've lived in vented the dryer through an exterior wall. Is venting a dryer through the roof unsafe? I don't see how it can work.

Lots of houses vent the dryer through the roof, so I wouldn't say it's unsafe—I would say it's not desirable. The exhaust stream from the

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DIY

Home HOMEOWNERS CLINIC Q+A

dryer is fighting gravity the entire way, making it almost certain that you need a booster fan in the dryer duct. It's important to clean the dryer duct regularly, which is difficult if it exits through the roof. You need to get into the attic, disconnect the duct from the booster fan, and inspect and clean the fan blades. One manufacturer, Fantech, recommends doing this every six months!

You also need to periodically inspect and clean the vent cap, which has a sharp internal bend in it. Cleaning a typical dryer duct takes only a few minutes to an hour. You'll probably need twice that amount of time to do the same job on a roof vent.

My final objection is one of aesthetics. A roof vent can leave ugly lint deposits on shingles.

Bottom line: If it's the only way to vent the dryer, that's one thing, but I'd investigate other options.

Up Against the Wall ➔ **we bought some very inexpensive but beautiful face-frame kitchen cabinets at a store that sells recycled building materials, but nobody we've talked to agrees on the size and type of screw for attaching them to each other or to the wall. Please help.**

That makes sense. There are many different cabinet types and materials, and there isn't one size or type of screw that will work with all of them. It wasn't that long ago that many carpenters went merrily about their business, putting in cabinets with nothing more than drywall screws. These aren't designed for wood-to-wood fastening, especially for heavy, concentrated loads produced by a cabinetful of dishes and glassware. If someone has told you to use drywall screws, disregard that advice.

Also, given that they are recycled cabinets, I wouldn't advise using the screw holes from the previous installation. You don't want to drive a screw into an existing hole and hit a snapped-off fastener lurking there, or find that the original installation was sloppy and using those holes pulls the cabinet face

frames out of line. Bore fresh pilot holes and cover the old ones with tinted wood filler such as Color Putty.

Home centers, lumberyards, and online woodworking supply houses (rockler.com, for example) sell a specialized screw that's ideally suited for fastening kitchen cabinets to the wall. It goes by different names: cabinet screw, washer-head screw, washer-head cabinet screw, or button-head screw. Its large-diameter head bears down firmly on the cabinet's hanging rail, ensuring a solid installation. Attach the cabinets to the wall using No. 8 or No. 10 screws, approximately 3½ inches long. The best make of this screw that I've seen is the one by GRK. It has a corrosion-resistant finish, an aggressive wood-cutting thread shape, and an extremely sharp split tip that makes it easy to start.

To attach the cabinets to each other, use a No. 8 2¼-inch-long trim-head screw with a fine thread suited for hardwood. This fastener's small-diameter head is unobtrusive, so you don't have to hide it under a cap or wood plug.

By way of general advice, there are a variety of tools you'll need for this installation: a stud finder, drill bits, and countersink bits to make the pilot holes for the screws; two carpenter's levels (a 2-foot one and a 4-foot one); clamps for holding the cabinet face frames in position as you bore the screw holes; and, of course, a reasonably powerful drill driver. I prefer an 18-volt model for this work. Mind you, you also need general carpentry tools such as a circular saw (for cutting filler strips), a chalk line, a razor knife, and a chisel. A small laser level is certainly helpful, though not absolutely necessary. **PM**

Got a home-maintenance or repair problem? Ask Roy about it.

Send your questions to pmhomeclinic@hearst.com or to Homeowners Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.





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Pipe Chime

A SIMPLE ASSEMBLAGE OF PIPE, TWINE, SCREWS, AND LUMBER USES ANCIENT GREEK GEOMETRY AND THE PENTATONIC SCALE TO COAX A SWEET SONG FROM A GENTLE BREEZE. BY WILLIAM GURSTELLE

1 → GATHER MATERIALS

Round up at least 5 feet of Type M $\frac{3}{4}$ -inch copper tubing, seven eye screws, five No. 6 1-inch machine screws and nuts, nylon twine, and 1 x 6 lumber.

2 → MAP PIPE MOUNTS

Center a $4\frac{1}{2}$ -inch-diameter circle in a $5\frac{1}{2}$ -inch-square cut of lumber. Mark the circle at five equidistant points. Insert eye screws at the circle's center and at all five points.

3 → CUE PYTHAGORAS

Cut five pieces of tubing to the lengths in the table below and deburr. The chime's five notes, which correspond to a piano's black keys, make up the minor pentatonic scale. The notes are pleasing in any order. The ancient Greeks such as Pythagoras were the first to study the link between the length of a vibrating body and the notes of a musical scale.

4 → TIE WITH TWINE

Drill a $\frac{5}{32}$ -inch hole through each pipe as listed in the table. These hanging points produce the best chime resonance. Insert a machine screw through the hole and fit a nut onto the screw shank. Tie a 7-inch length of twine from the circle of eye screws to the screw shank in each pipe.

5 → HANG THE CHIME

Use a $2\frac{1}{2}$ -inch holesaw to cut a clapper from a 1x scrap. Use more 1x waste to make a V-shaped, 3-inch-long wind scoop. Hang each from the center eye screw. Cut and glue two smaller 1x squares to the top of the first square. Top-center-mount an eye screw in the smallest square. Hang the chime in the breeze and enjoy.



MUSICAL PITCH	LENGTH $\frac{3}{4}$ -inch copper	HANG POINT from top
C-sharp	11 $\frac{1}{2}$ inches	2 $\frac{1}{16}$ inches
D-sharp	10 $\frac{7}{8}$ inches	2 $\frac{3}{16}$ inches
F-sharp	10 inches	2 $\frac{1}{4}$ inches
G-sharp	9 $\frac{5}{8}$ inches	2 $\frac{1}{2}$ inches
A-sharp	8 $\frac{7}{8}$ inches	2 inches

Start Smithing

→ Learn to work metal by the banks of the Mississippi with master blacksmith Alfred Bullermann at Memphis, Tenn.'s Forging on the River, March 30 to April 1.

Get Rare Scrap

→ Find a rare part to finish a project and network with like-minded craftsmen at the St. Charles Machinist Hall Swap Meet March 3 at the Bridgeton Machinist Hall in St. Louis.

Know the Ropes

→ As spring projects begin, call the building department to see which jobs require permits. Dull, yes, but worth the effort. A violation can lead to a work stoppage or fine, and penalties can come years later when selling the house or filing insurance claims.

Stack Stones

→ Learn how to build dry-laid retaining or freestanding walls at Queen City Soil & Stone's stone-wall workshop March 10 and 17 in Hinesburg, Vt.

Make a Motor

→ Every Tuesday afternoon in March, aerospace engineers (and parents) George Kirkman and Bing Jiang teach kids age 5 and up to wire circuits, make electromagnets, and build simple motors at Glendale, Calif.'s Tech Starter workshops.

DIY

Auto

Saturday
Mechanic degree of difficulty
MODERATE

➔ **Electric-powered**, self-extending antenna masts used to be a telltale sign of a fancy, feature-laden car. As is the case with many electro-mechanical parts, however, power antennas usually end up requiring repair. Run through a carwash with one extended and you'll have what looks like a bent hanger sticking out of the fender. Today, power antenna masts have been replaced with fixed antennas or wires embedded in windshields, but there are still plenty of cars out there with these telescoping menaces. Broken antennas get stuck all the way up, all the way down, or often somewhere in between. The shabby appearance of, and stunted radio reception on, an otherwise perfectly good car means that replacing or repairing an antenna is a worthwhile fix.

It's almost too bad these have gone out of style; they are actually pretty elegant in a Rube Goldberg kind of way. An electric motor hidden below the fender turns nylon gears that eventually mesh with a toothed nylon rope matching the gears. That rope extends all the way through the hollow antenna sections and mounts to the tip. As the motor turns the

Stuck at Half-Mast

TELESCOPING ANTENNA MASTS ARE ALMOST EXTINCT, BUT IF YOU HAVE ONE, IT WILL EVENTUALLY NEED TO BE FIXED.

BY BEN WOJDYLA

INSIDE

✕

COMPACT SPARES + STICKER SHOCK + THERMAL FLASHER

DIY

Auto POWER-ANTENNA REPAIR

gears, the rigid rope is pushed or pulled and the mast advances or retracts, stopping based on either a digital counter or timer or on a measured spike in voltage when the motor can't turn anymore.

As you might imagine, there are several ways these antennas malfunction. The most prevalent is a bent mast—even slight tweaks to the tight-fitting telescoping tubes can cause havoc. The nylon bits are a problem,

too; teeth from the gears or rope break off from wear or cold or the rope snaps along the length. Sometimes the antenna fails when the components just plain get dirty—rain and dust infiltrate the mechanism, and things grind to a halt. Below we're going to walk through the general steps of removing the whole assembly, taking it apart, then cleaning and replacing the problem parts.



STEP ONE Extract the Problem Part

First, you'll need to get to the mechanism. If the antenna is rear-fender-mounted, remove the trunk trim panels to gain access. Front-fender units may be inside the engine bay or behind the inner fender. You'll likely need a few screwdrivers and wrenches. The mechanism is usually easy to remove—loosen any bolts and

disconnect the ground strap, antenna signal wire, and motor-control wires. Be careful with the connectors because they will be reused. Remove the assembly by pulling the antenna mast down through the fender.

STEP TWO Dissect and Diagnose

Uncover the device's guts by extracting the cover screws. Carefully remove the

housing and gear cover, as the nylon cord within might spring out and fling smaller parts. Inside, you'll see how the motor, gears, and nylon rope work together. If the teeth on the rope or gears are stripped, you'll need to remove all the broken pieces.

There will undoubtedly be old, dirty grease that may or may not be the problem but should be cleaned out. Inspect everything else for signs of damage; if a major part such as the housing or motor is broken, replace the whole assembly.

STEP THREE Fix the Bits

If the telescoping mast is the problem, remove it by taking off the bushing at the top of the guide tube; it keeps the mast in place. With a firm grip, pull the mast out along with the nylon rope; pliers may be needed. Clean everything, including the gears, with a mild cleaner like dish detergent. Lubricate the clean gears and housing with white lithium grease; it works well even at low temperatures.

STEP FOUR Reinstall the Unit

If new gears are called for, assemble them as before; most of the time they just drop into place. Compress the mast completely and run the nylon rope down

the tube, then seat the base into the housing. You may need to gently tap it home with a hammer. Fully extend the antenna, then mesh the end of the nylon cord back into the gear drive and reassemble the cover and housing. With the mechanism still loose, plug in the electrical connections, then turn the radio on and off. This should cause the gears to pull on the nylon rope and retract the mast. If the mast doesn't go down, the gears of the nylon rope may not be properly aligned, so you'll have to try again. Reinstall the assembly and bolt the mast bushing back in place. Now enjoy one less annoyance, at least until you forget to turn off the radio in a carwash again. **PM**

Car Clinic

by Ben Wojdyla

SPARE TIRE

Dimensions:
T125/80/R16

Outside diameter:
23.8 inches

Max speed:
80 mph

FULL-SIZE TIRE

Dimensions:
215/55R16

Outside diameter:
25.31 inches

Max speed:
130 mph



Spare the Tire

I had a flat tire a while ago, so I mounted the space-saver spare. I'll admit I left it on for way longer than the owner's manual suggests. Eventually, I replaced it with a full-size tire, but I've always wondered why manufacturers say you shouldn't use the spare for longer than necessary.

Compact spare tires are designed to get you home, not across the country. Like almost all spare tires, the one on this Ford Focus

is recommended for no more than 50 miles of driving; anything more and you're asking for poor handling and a possible blowout.

A Since the spare tire is used so infrequently, carmakers have switched to narrow, compact spares to save space and weight. Of course, a spare tire is a lifesaver when regular tires go pop, but leaving the temporary tire on for longer than the manufacturer recommends invites a host of problems. First, a temporary spare isn't as durable as a normal tire. The real strength of a tire comes from the plies—layers of steel and polyester underneath the rubber—and spares don't have as many plies as regular tires. A typical space-saver spare has only one layer of polyester in the sidewall and two belts of steel with a layer of polyester in the tread—about half as many plies as a normal tire. This greatly limits puncture resistance and cornering ability. In addition, as the name implies, space-saver tires are intended to take up less room in car and crossover trunks so that those trunks can be deeper. For that reason, these tires are narrower and have a smaller contact patch. This reduces the amount of traction for the tire, increasing stopping distances and making handling potentially unpredictable in emergency maneuvers. It also means ABS and traction control aren't as effective at keeping you out of danger. And you're not going to have the same ground clearance. If you're towing a trailer, you'll have to

leave it behind—spares have much lower load ratings than regular tires. Long-term use of the spare can cause a serious mechanical issue, too: The smaller-diameter tire can put a lot of stress on your differential.

The differential has a tricky job. It transmits engine power to the wheels from the transmission, but it also lets the left and right wheels turn at different speeds. This is essential for cornering. In a turn, the path of the inside wheel is shorter than that of the outside wheel, which means they travel at different speeds. When your car is driving in a straight line, the differential isn't

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DIY **Auto** CAR CLINIC Q+A

in use and there's little wear and tear on its gears and bearings. But because the spare is smaller than the opposing wheel on the same axle, it must turn faster to keep up with the speed of the car, making the differential work to account for the variation. It's as if the car is constantly in a turn. Leave the spare on long enough and the grease lubricating the differential will begin to break down, accelerating wear between the gears and the clutch plates if it's a limited-slip differential. For all these reasons, manufacturers suggest keeping speeds below 50 mph and using the spare tire only for limited distances if possible. If a compact spare is ever damaged, either the tire itself or the wheel, the entire spare should be replaced rather than repaired. And don't forget to check the pressure in your spare every time you check the pressure in your other tires—it's important to make sure your safety net is, in fact, safe.

Sticky Situation ➔ I got a great deal on a low-mileage 1990 Mustang GT, one of those little-old-lady liquidation cars everyone dreams about. The only problem is, it came with quite an array of bumper stickers that I didn't particularly want to leave on. I peeled them all off, but the entire back of the car is covered with sticky residue and none of my regular cleaners can get it off. I'm wondering if I can use my buffing wheel, or if you have a better idea?

I've been there—you find a cherry used ride and there's something stuck to the back you want nothing to do with. While a buffing wheel and some compound could remove the residue, that's not what those tools really are designed for. Anyway, there are two products that will remove the sticky stuff quickly and easily. One is good old WD-40. Spray it on and let it sit for about 5 minutes, then wipe it away with a cloth. You may have to repeat the process a few times, but it always works. I like to use something called Goo Gone for this task, though. In my experience, it gets even the most stubborn goop off in the first try, without damaging the surface underneath it. When you've got all the sticker leftovers cleaned away, the paint will probably be scuffed up and splotchy. Break out the wax and give the area a once-over, and that Mustang will have a rear end you can be proud of.



PM TOOLBOX

TOOL INDULGENCE

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Flash Dancing ➔ I have an old '95 Yukon with high mileage. The rear turn-signal lights have started flashing very rapidly. I always thought this was caused by a burned-out bulb, but both the front and rear lights are flashing quickly. How do I fix this?

Start by looking at the widget that makes the signals actually blink, the thermal flasher, aka the turn-signal relay. For most of its history, the relay has remained largely unchanged. It works by passing current through a thermal element that heats up, expands, and closes a connection between the 12-volt power source and the bulb sending power to the turn signal. The thermal element then cools and contracts because the current isn't passing through it, opening the circuit and turning off the light. The most likely cause of your rapid flashing is that the relay has worn out and the springs it rests on have lost their bounce. Fixing the problem is easy and cheap. Head to your local auto parts store and ask for a turn-signal relay for your Yukon. They'll hand you a small, round, metal part that looks a bit like a little stockpot turned upside down. Root around in your fuse panel to locate the matching part and replace it—your owner's manual or the lid of the fuse-box cover will help you find where this part is hiding. Most of the time, the replacement part looks almost identical to the original. Switching the parts is as easy as pulling the old one out and popping the new one in. **PM**

Got a car problem?

Ask Ben about it. Send your questions to pmautoclinic@hearst.com or over Twitter at twitter.com/PopMechAuto or to Car Clinic, Popular Mechanics, 300 W. 57th St., New York, NY 10019-5899. While we cannot answer questions individually, problems of general interest will be discussed in the column.



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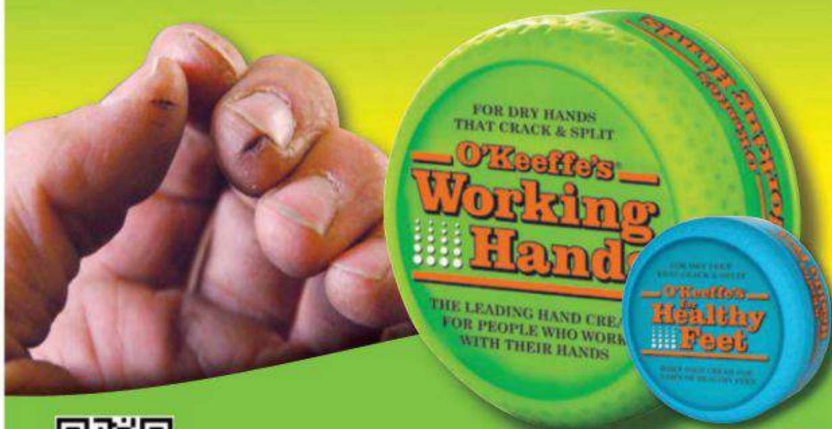
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7.8.11

The Fast and the Curious

(CONTINUED FROM PAGE 83)

judge who was inspecting VWP. "You'd tell us if this thing was going to fall apart, right?" I asked.

"Oh, heck no," he said. "We hope for sinkers." But VWP crosses flawlessly. Styrofoam pontoons on each side of the craft keep us afloat. Paddle blades made from cut-up paint buckets and temporarily mounted on the wheels supply the propulsion.

Ransom is upset that VWP didn't do better on the climb up Dead Man's Drop, but is excited at how well we handled the water crossing. The strength of his reactions is a revelation: The inventors behind this rolling circus take their contraptions seriously. It isn't that most participants are out to be the fastest on the course—one of the most coveted prizes is the Medio-CAR Award, given to the team that finishes exactly in the middle. Instead, artistic flair and engineering ingenuity are what's valued. The race is not about who can get to Ferndale first, but who can get there best.

Late in the race, VWP pulls abreast of Bottom Feeders on a long hill. I look over at Flatmo; he looks over at me. We point at each other in mock menace, then both start pedaling madly. Dune buggy and sea monster trade leads for 30 yards, but then the sound of a popping chain comes from Bottom Feeders. They pull over for a quick repair as we laugh and continue on.

We reach the top of Loleta Hill, which punishes racers with 1 mile of 7 percent grade, and dismount to catch our breath. In the end, Team VWP will finish in the middle—not fast enough to win a top prize, nor average enough for the Medio-CAR Award. But Ransom is happy simply because his machine has held together. "Blood, sweat, and gears," he says to nobody in particular, and hops back aboard.

PM

Unacceptable Risk

(CONTINUED FROM PAGE 77)

violation the year before, when off-duty drivers were found to be using the underbelly as a sleeping berth.

Once behavior becomes egregious enough for the FMCSA to order a company shuttered, a secondary challenge is posed by so-called chameleon operations. "The problem they're having now is finding these companies that want to hide from them," Littler says. "They change names, they use false DOT numbers, they park their buses in different locations. They don't want to be found."

After the Doswell, Va., crash, the FMCSA issued Sky Express an Unsatisfactory safety rating, which placed the company out of service. Within days, Sky Express had reincarnated itself, with the same management selling tickets for the same buses under the company names 108 Tours and 108 Bus. Tickets were available from a variety of websites, including 2001bus.com, gotobus.com, and taketours.com.

"This behavior by a few is outrageous and must be stopped," FMCSA head Anne Ferro testified before Congress in June. By then, the agency had issued a cease-and-desist letter to Sky Express. "This year has been the worst period in recent history for motorcoach safety," she said. Ferro explained that loose leasing practices allow rogue carriers to escape detection, while unregulated websites broker and sell tickets with no transparency to the public.

Ferro argued that her agency needs more congressional authority to tighten the net around unsafe operators. It needs the power to require safety audits before a carrier ever starts operating. (Today, a new company can transport passengers after two online payments of just \$300.) It needs to be able to conduct unannounced, en route inspections at rest stops or other safe pull-offs, rather than before or after trips as is now the norm. And it needs a way to stop "new" companies that rise from the ashes of unsafe carriers. A good start, she said, would be to raise the penalty for companies that attempt to operate without DOT authority from the current \$2000 a day to \$25,000 per violation.

TECHNOLOGY UPGRADES WOULD

no doubt save lives, too. The bus industry has lagged behind passenger vehicles when it comes to safety advances. While annual interstate bus fatalities have risen, overall road deaths are down 25 percent since 2005 and are now at a historic low. Safer roads, stepped-up enforcement, and stricter teenage-driving and drunk-driving laws are responsible for much of the drop. But the now-ubiquitous use of seatbelts, stronger vehicle construction, and technologies like antilock braking in cars have also made a big difference.

About 70 percent of people killed in bus crashes are ejected from the vehicle; break-free glass and stronger construction standards for roofs would reduce the death toll. (In the Bronx crash, the signpost sliced through the bus, peeling the roof back like the lid on a can of sardines.) Antilock brakes should be standard in motorcoaches, which take much longer than passenger cars to slow and stop. And though the NTSB first recommended mandatory seatbelts in buses in 1968, they're still uncommon. Some manufacturers have begun building vehicles with three-point belts, but a DOT proposal to require belts in every new bus would speed this transition.

A smartphone app that ranks all carriers in a given departure city by their safety scores would go a long way toward helping travelers choose wisely. In the meantime, passengers can be proactive about minimizing risk: Bus companies' safety data can be searched on the FMCSA's website (look for Bus & Passenger Carrier Safety under Quick Links).

But for too many people, budget trumps safety concerns. Zhenjiang Qian, a Chinese tourist who was traveling to D.C. aboard Mike Lin's Eastern Coach route, had read about some of the recent bus accidents in the paper but still opted for a low-cost ride. "The bus tickets at Port Authority [New York City's bus terminal] cost \$70 round-trip," he told a reporter. "This one is much cheaper." Absent stricter regulation, the seats of unsafe carriers remain filled. To Qian and others, until the worst happens, a \$20 ticket seems worth the gamble. **PM**

Additional reporting by Yiting Sun



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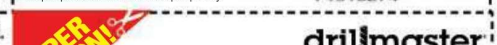
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MOVER'S DOLLY
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90 AMP FLUX WIRE WELDER
CHICAGO ELECTRIC

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LOT NO. 2745/69094

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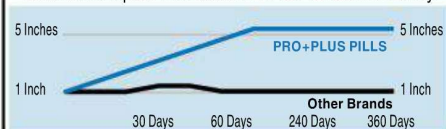
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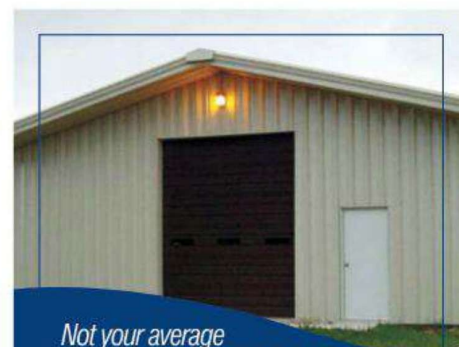
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Name: GEORGE DODWORTH
Location: CANONSBURG, PA.
Age: 37
Years on Job: 16

1. LASERS

Inside a laser projector, a variety of lenses, beam splitters, and electronics controls the beam of light. By mixing high-efficiency solid-state diode lasers in six colors—blue, cyan, gold, green, red, and violet—Dodworth can create 2.8 trillion color variations. Electrical signals control tiny mirrors inside the projector that move at 60,000 times per second, allowing Dodworth to “draw” animations.

2. GOGGLES

A rogue beam can harm eyes, so Dodworth dons goggles coated with metal oxides that reflect the bandwidth of light used by lasers. At shows, beams are typically required to be 10 feet above the audience. But by using equipment that keeps power low, moves beams quickly, and limits pulses in a given time period, Dodworth can safely direct effects into a crowd. “Don’t try this at home,” he says.

3. COMPUTER

Dodworth uses special laser software to create his effects. Customized hardware on the computer converts his digital code into analog signals that manage the color of each beam and its movement.

4. MIRRORS

On show day, Dodworth installs and aligns lasers, as well as 4- to 12-inch silver-coated mirrors that direct beams. He rotates each mirror into position with fine-pitch screws—100 turns per inch—as he guides the source beam remotely with an iPad app.

✕ **The first time George Dodworth saw a laser light show**, he was mesmerized. The 11-year-old decided right then to create his own. Twenty-six years later, Dodworth’s company, Lightwave International, is one of the biggest laser-entertainment providers in the world. He has fashioned special effects for Hollywood movies, designed light shows for Kanye West, Jay-Z, and Madonna, and projected Nike’s logo onto a mountain for the Fiesta Bowl. As an electrical engineer, Dodworth is involved in every aspect of his craft, from building the equipment to devising new ways to control the beams. The hours can be grueling, but the lifestyle glamorous. “You meet the biggest stars, directors, and lighting designers,” he says. “But we just go in humble and do our jobs.” — OLIVIA KOSKI

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